CASE WESTERN RESERVE UNIVERSITY

SCHOOL OF DENTISTRY

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We hereby approve the thesis of

GORDON S. GROSSER

candidate for the degree Master of Science

in Dentistry.

Signed: _____ (Chairman)

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THE EFFECT OF ORTHODONTIC TREATMENT WITH ALL FOUR FIRST MOLAR EXTRACTIONS ON THE VERTICAL DIMENSION OF OCCLUSION

by

GORDON STEVEN GROISSER

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School of Dentistry

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THE EFFECT OF ORTHODONTIC TREATMENT WITH ALL FOUR FIRST MOLAR EXTRACTIONS ON THE VERTICAL DIMENSION OF OCCLUSION

Abstract

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The primary purpose of this investigation was to test the "wedge hypothesis;" i.e., does removal of first molar teeth from the wedge result in reduced anterior facial height subsequent to orthodontic treatment. Particular skeletal and dental components of the vertical dimension of occlusion were measured in subjects who had four permanent first molars extracted in conjunction with orthodontic treatment and compared to untreated controls. Additionally, an analysis of the change in vertical dimension between pre-treatment and post-treatment for the treated subjects was performed and compared to the untreated controls for the same interval. The analysis also examined differences based on sex.

Thirty patient records were provided by ten orthodontists using the criteria that the permanent first molars were extracted after the Time 1 cephalometric radiograph and prior to orthodontic treatment. A paired control sample of untreated individuals with similar mean age and time interval of observation was chosen from the Bolton Collection, Cleveland Ohio.

A cephalometric analysis was utilized which contained six linear and two angular measurements to evaluate dental and skeletal changes for both the treated and the control groups. The analysis isolated tipping movements from bodily movements of the upper and the lower incisors and assessed vertical skeletal changes in the maxilla and the mandible.

Analysis of the data revealed no statistically significant differences in the variables between Time 1 and Time 2 treatment and control groups. However, overbite did slightly increase in both. It was observed that the change in the variables in the treated group could be largely attributed to growth and not to orthodontic treatment or extractions. Moreover, first molar extractions seemed to result in relatively reduced mandibular skeletal height in males. This effect was not seen in the female treated group in which much less growth was seen. Therefore, it can be concluded that extraction of four first permanent molars does not affect the vertical dimension of occlusion in this sample.

DEDICATION

To my wife Patricia, daughters Kailyn and Kara and our future third child, God willing. Your love will always sustain me.

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INTRODUCTION

The treatment of orthodontic patients with high mandibular plane angles and increased lower anterior facial heights presents a challenging problem to clinicians. Frequently enough either the patient already has an anterior open bite or is at risk for developing one if the initial overbite is already reduced. Extraction of posterior teeth has been accepted by many clinicians in the treatment of open bite, most frequently the extraction of first premolars.

Isaacson et al. (1971) suggested that if the molar teeth were moved forward from the palatomandibular wedge without extrusion towards the extraction spaces of the first premolars, the mandible might show an anterior rotation. Some authors prefer extraction of the first molars, particularly in patients with a skeletal anterior open bite extending to the posterior teeth (Frankel and Frankel, 1986). Aras (2002) found that extraction of the second premolars or the first molars led to a closing rotation of the mandible in skeletal anterior open bite extending to the posterior teeth. Besides Aras, literature concerning all four first molar extractions consists mostly of case presentations, while statistical data are available for patients treated with first premolar extractions. The case reports indicated that forward movement of

the second molars after first molar extraction lead to anterior rotation of the mandible. (Arvystas 1977; Cooke and Newsome 1990; Ortial 1995; Vaden 1998).

The purpose of this investigation is to determine whether the extraction of the four first molars and subsequent orthodontic treatment in growing subjects has a significant impact on vertical dimension. A cephalometric analysis (Kishiyama 1987) that employs six linear measurements and two angular measurements will be utilized to evaluate the dental and skeletal changes that occur during orthodontic treatment. This analysis isolates tipping from bodily movements of the upper and lower incisors and assesses vertical skeletal changes in the maxilla and mandible.

LITERATURE REVIEW

According to James Vaden and Lloyd Pearson (2002), the human face has been the subject of study since man could first express himself. During the Renaissance, da Vinci, Michaelangelo, and Duhrer led other artists to study faces. In the specialty of orthodontics, Angle (1900) was vitally concerned about the face: "Our opportunities for benefiting humanity are very great in this field, far exceeding those offered by any other branch of dental science." The underlying theme that surfaces from many artists and orthodontic investigators is the concept that there cannot be good balance and harmony in the lower face unless the vertical dimension is within normal limits. The most important prerequisite for facial balance is a normal vertical dimension of the lower face (Vaden and Pearson 2002).

Macgregor (1970) stated that the person with buckteeth or a receding chin is less apt to be viewed with compassion and can be a target for teasing, nicknames, or caricature. For the victim, derisive laughter is one of the most potent and destructive instruments men can use and the shame, anger, and distress it can generate is immeasurable.

DeSmit and Dermaut (1984), in their study of soft-tissue profile preference, created three different series of nine profile photographs that were ranked according to personal aesthetic preference by graduate dental

students. The authors grouped the profiles into (1) open types (Angle class I, II, III), (2) vertical normal (class I, I, III) and (3) deep types (class I, II, III). Their study suggested that open bite profile types were clearly the least appreciated. In profile evaluations, lengthening of the soft-tissue profile in the vertical dimension was not desirable in most cases.

Klontz (1998) stated that facial balance was an attainable goal of orthodontic treatment. He was concerned with what orthodontists should do to enhance facial harmony and proportion when the patient has a medium to high Frankfort mandibular angle, or stated differently, a moderate to excessive anterior facial height. He believed that posterior vertical dimension must be controlled, as well as anterior facial height.

Definition of Anterior Open Bite

According to Subtelny and Sakuda (1964), open bite must be considered as a deviation in the vertical relationship of the maxillary and mandibular dental arches. In an open bite, there should be a definite lack of contact, in the vertical direction, between opposing segments of teeth. The degree of openness can vary from patient to patient, but an edge-to-edge relationship, or some degree of overbite, cannot be rightfully categorized as an open bite. An anterior open bite is one in which there is a lack of contact in the vertical dimension between the incisal edges of the maxillary and mandibular anterior teeth. While this situation exists, some of the buccal teeth are in definite occlusal contact. On a cephalometric headplate, taken with the

teeth in occlusion, there must be a definite separation between the upper and lower incisal edges when measured relative to the occlusal plane or to a perpendicular to the palatal plane. Nahoum (1977) states that although the interincisal opening is basic to the definition of anterior open bite, it can be misleading in terms of diagnosis unless this measurement is correlated with facial measurements and with the developmental stage of the subject. McSherry (1996) similarly defined anterior open bite as a vertical occlusal anomaly where there is no vertical overlap of the upper and lower incisors. Mizrahi (1978) proposed this definition: "Open bite is that condition where the upper incisor crowns fail to overlap the incisal third of the lower incisor crowns when the mandible is brought into full occlusion."

Worms et al. (1971) defined anterior open bite as the absence of contact between the maxillary and mandibular incisors in centric relation. Those patients who had open bite but, when sighted along the occlusal plane, showed vertical overlap of the maxillary and mandibular incisors were classified as having pseudo-open bite if the open bite was less than 1 mm.

Classification of Anterior Open Bite

Numerous authors have attempted to classify anterior open bite. Nahoum (1975) grouped it into two broad categories. The first category consists of the acquired or dental open bite, which does not show any distinguishing craniofacial malformations. The dental open bite is believed to result from obstructed eruption of the anterior teeth. There will probably be

inadequate development of the anterior alveolar processes as well as incomplete eruption of the incisor teeth. The second category consists of patients with craniofacial dysplasia in addition to the open bite. These subjects have varied characteristics which continue on into maturity. These subjects usually have slightly longer total anterior face height. The ratio of the upper anterior face height (UFH) to the lower anterior face height (LFH) serves as one of the diagnostic criteria. The normal UFH/LFH ratio is 0.800, open bite < 0.700 and closed bite > 0.900. The posterior face height is usually shorter than the norm. An obtuse gonial angle is seen with a steep, notched mandibular plane. The dentoalveolar height is usually normal except for the mandibular molar, which is often significantly shorter.

Watson (1981) similarly divided open bite into two general categories for diagnostic purposes: (1) dentoalveolar, in which skeletal components of the individual are relatively normal, and (2) skeletal open bite, in which there is a discrepancy in the cranial base, mandible, and/or maxilla. He noted the magnitude of difficulty in correcting some open bite cases, partcularly those in which skeletal open bite had been corrected with orthognathic surgery. If the anterior facial height was reduced and the cause was an inability to make a proper lip seal, reasonable success could be achieved. However, if the problem was chronic swollen nasal mucous membranes with nasal obstruction, surgery became an exercise in futility.

McSherry (1996) used a simple classification based on etiology. The possible causes were either skeletal (growth rotation, facial growth and airway resistance), acquired (habits, trauma, pathological and iatrogenic causes), soft tissue morphology (endogenous tongue thrust, abnormal swallowing patterns) or neurological causes (mental handicap). Habits such as thumb, digit or non-nutritive sucking are in the acquired category. Trauma that might result in bilateral fractured condyles and juvenile rheumatoid arthritis are examples of pathologic conditions that can result in anterior open bite. Poor orthodontic treatment can cause an iatrogenic open bite as well.

Richardson (1981) advanced a classification of open bite that was also based on etiology. Transition open bite and those due to habits, local pathology (if treated) and the soft tissues tended to improve during the pre-pubertal (7-10 years) and pubertal (11-14 years) periods. Those due to skeletal pathology tend to appear and deteriorate during the post-pubertal phase (15-21 years). There was also a category of non-pathological open bite where the shape of the facial skeleton was a determinant factor in the development of open bite.

Subtelny and Sakuda (1964) proposed another scheme based on etiology. Open bite was divided into three groups, vertical growth deficiencies, muscle aberrancies and digit habits. The authors acknowledged that a variety of previous studies offered differing opinions with regard to the exact area reflecting the vertical growth deficiency. In their cephalometric study, the

skeletal-dental relationships of twenty-five subjects with persistent open-bite were compared with a group of thirty subjects with normal occlusion. All subjects were over twelve years of age. The most common skeletal deficiency was the reduced height of the ramus in skeletal open bite subjects. Muscle aberrancies included disproportionate muscle growth and aberrant muscle function. The enlarged size or protrusive function of the tongue prevented full eruption of anterior dental units or exerted a disfiguring effect on the molding of the anterior dentoalveolar processes. Digit habits included both thumb and finger sucking habits.

Characteristics of Anterior Open Bite

In 1964, Schudy stated that vertical dimension was the most important dimension to the clinical orthodontist and vertical dysplasias were inseparably related to both open and closed bites. He also stated that retrognathic persons were likely to exhibit greater lower face height, whereas prognathic persons were more likely to exhibit shorter lower face heights. In computing the ratio of posterior (PFH) to anterior face height (AFH), he measured posterior face height from articulaire to the mandibular plane, tangent to the posterior border of the ramus at the gonial angle. Anterior face height was measured from nasion to menton. He found that the PFH/AFH ratio was 62.91% in an average group, 57.23 % in a retrognathic group and 69.28% for a prognathic group.

Beane (1999) stated that the dental open bite was associated with normal craniofacial pattern, proclined incisors, undererupted anterior teeth, normal or slightly excessive molar height, and thumb or fingersucking habits. The open bite was generally found in the anterior region within the area of the cuspids and incisors. The craniofacial characteristics most consistently associated with the skeletal open bite were increased mandibular plane angle, increased gonial angle, long anterior facial height, increased total facial height, palatal plane tipped up anteriorly and retrognathic mandible.

Hapak (1964), in a cephalometric appraisal of open bite, concluded that open bite occurred with a variety of skeletal patterns. His sample showed a class II tendency and proved to be retrognathic on Downs' facial diagram. The sample also showed high Frankfort-mandibular plane angles above 33.4° and a mean sella-nasion to GoGn angle that was 6.3° greater than normal.

Richardson (1969) found significantly greater lower face heights and greater jaw and joint angles in open bite cases. He concluded that the cause of open bite in the 7-10 year age group was delayed vertical growth of the upper face and increased lower face height, combined with a lack of vertical growth of the dentoalveolar structures. The growth of the upper face corrected itself but the vertical development of the dentoalveolar structures will never catch up. So, the anterior open bite was due to both skeletal and dentoalveolar characteristics.

Kim (1974) developed an index callled the Overbite Depth Indicator ODI). In his study of 119 persons with normal occlusion and 500 persons with various malocclusions, ODI had a high correlation with incisal overbite depth. The ODI was a combined (additive) measurement of the angle of the A-B plane to the mandibular plane and the angle of the palatal plane to the Frankfort horizontal plane. Kim did not believe that the traditional use of the mandibular plane angle as a reliable indicator of overbite-whether deep or open- was justified.

Moss and Salentjin (1971) studied the position of the inferior alveolar nerve in a large series of skulls of various dental ages. They placed metallic implants in the foramen ovale, the mandibular foramen and the mental foramen. They noted on the lateral cephalogram that the three foramina of the inferior alveolar nerve fall on a logarithmic curve. In open bite cases the foramen ovale is consistently lower in position than in non-open bite cases. They attributed this to developmental abnormalities in the multifunctional oral space.

Nahoum (1977) found that the ratio of upper face height to lower face height was smaller for open bite subjects and this ratio was constant at all ages. He also found that the SN to palatal plane (SN-PP) angle was smaller and the PP-GoGn angle was greater in open bite subjects. These findings suggested a tipping upward of the palatal plane anteriorly. Nahoum also

concluded that persons with open bite generally had greater lower anterior face height, shorter posterior face height and greater gonial angles.

Cangiolosi (1984) made linear and angular measurements on lateral cephalometric films of sixty normal and sixty open bite subjects. His studied confirmed that of Nahoum (1977). However, Cangiolosi did not find that his open bite sample had a significantly smaller SN-PP angle when compared to his normal sample. Cangiolosi concluded that the increase in the PP-GoGn angle, resulting in greater lower anterior face height, was caused by a downward tipping of the mandibular plane.

Sassouni and Nanda (1964) studied the vertical proportions of the face by examining longitudinal cephalometric records of eight persons with skeletal deep bite and eight persons with skeletal open bite. They identified three significant differences related to the mechanism of origin of skeletal open bite as compared to skeletal deep bite: (1) the condylar position was higher in open bite cases; (2) the maxillary molars were more extruded in open bite, and (3) the ramus was shorter in the open bite cases.

Nanda (1990) analyzed the angular measurements of longitudinal lateral cephalometric radiograhs of sixteen male and sixteen female subjects grouped on the basis of lower face height (ANS-Me) as a percentage of morphologic face height (N-Me). Subjects were classified as either deep or open bite. He studied SN-PP, SN-MP, SN-OP, PP-MP and cranial base angle. With the exception of SN-PP and cranial base angles, all angular

measurements demonstrated a progressive reduction throughout development in both open bites and deep bites. The progressive reduction of angles in skeletal open bite reduced or maintained the imbalances. The inclination of the palatal plane and its constancy suggested that downward and backward rotation of the mandible in open bite subjects was pre-committed in response to dentoalveolar compensatory changes with the center of rotation at the molars. In a different paper on the same thirty-two subjects, Nanda (1988) observed that the anterior dimensions of the face demonstrated typologically divergent patterns of development in open bite and deep bite faces. Further, the posterior dimensions of the face did not discriminate between these two typological groups.

Bjork (1969) has contributed significant information about growth rotation of the mandible, which has recently been seriously questioned by Leslie et al. (1998) He described a structural method of predicting significant growth rotation from a single cephalogram. This method was based on information gained from implant studies of the remodeling process of the mandible during growth. The principle was to recognize seven specific structural features that develop as a result of remodeling in a particular type of mandibular growth rotation. He believed that the backward rotator (i.e., open bite) subject had (1) a condylar head that sloped up and back or is straight, (2) minimal curvature of the mandibular canal, (3) notched mandibular lower border, (4) inclination of the symphysis sloping forward, (5)

acute interincisal angle, (6) acute intermolar or interpremolar angles, and (7) increased anterior lower face height. Bjork did not think that all seven were present in every patient, but he hypothesized that the greater the number present, the more predictable was the mandibular growth rotation.

Leslie et al. (1998) disputed the usefulness of Bjork's method to predict mandibular growth rotation. Leslie's study analyzed forty randomly selected, untreated, adolescent subjects representative of the patient population generally encountered in orthodontic practice. Initial and final lateral cephalograms (taken six years later) were traced and superimpositions were performed. Actual mandibular rotation was recorded. Leslie et al. tried a variety of regression equations to determine if there was any predictive value of the independent variables identified in Bjork's study for mandibular growth rotation. It was concluded that information derived from pre-treatment lateral cephalograms, using Bjork's method, did not permit clinically useful predictions to be made in a general population relative to the direction of future mandibular growth rotation.

Isaacson et al. (1971) found that high angle and low angle subjects had similar upper face height development. Vertical height from the palatal plane to the maxillary molars was significantly greater in the high angle cases (22.5 mm) compared to the low angle cases (17.1 mm), indicating that posterior dental eruption was generally greater in high angle cases.

Epker and Fish (1977) described the general cephalometric features of open-bite deformity as follows: (1) steep mandibular plane angle, (2) increased anterior facial height occurring principally in the lower third, (3) normal mandibular body length, (4) normal ascending ramus height, (5) increased distance from nasal floor to canine and first molar root apices, (6) decreased posterior cranial base (S-basion), and (7) low position of the mental foramen.

Naumann et al. (2000) studied the multi-dimensional nature of overbite changes that occur during adolescence. They used longitudinal cephalograms of 181 untreated children taken at ages ten and fifteen. Their results showed that overbite changed minimally (0.2 mm) over the five year period; variation ranged from a 2.4 mm decrease to a 5.6 mm increase. The mandibular skeletal changes were twice as important as the mandibular dental changes and about 2.5 times as important as the maxillary changes in effecting overbite change. Within the mandibular skeletal component, vertical growth was more important than mandibular rotation in determining overbite change. They found that there were significant differences between the bite opening and bite closing groups for most of the measures used. The authors stated that the mathematical models developed in this study imply that in the case of open bite, the ideal appliance, yet to be developed, would limit vertical mandibular growth and augment its forward (counterclockwise) rotation were needed.

Kuhn (1968) identified diagnostic factors contributing to, or consistent with, mandibular opening. He mentioned steep mandibular and occlusal planes, large lower anterior face height, a smaller lower posterior face height a greater interincisal angle, bidental protrusion, congested airway, tongue thrust and/or detrimental tongue posture, occlusal disharmonies such as prematurities and atypical occlusal anatomy, flat occlusal anatomy, TMJ disturbances and weak masticatory musculature in conjunction with open-bite. Kuhn stated that some of these factors were hypothetical.

Janson et al. (1994) evaluated the maxillary and mandibular molar and incisor vertical dimensions of subjects from the Burlington Growth Center sample. These subjects had excessive, normal and short lower anterior face height (LAFH) in relation to upper face height (UAFH). Dentoalveolar height was significantly different between faces with excessive, normal, and short LAFH, except for the lower posterior dental height. Dentoalveolar height was similar in class I and class II dental and skeletal malocclusions.

Karlsen (1995) studied craniofacial growth longitudinally in two groups of boys with lower and high MP-SN angles. Interestingly he found a rather optimistic picture regarding the craniofacial growth patterns of high MP-SN angle cases. The high angle group had no cases of posterior total rotation of the mandible (ages 6-15). Further, his findings confirmed that dentoalveolar mechanisms had a great potential in compensating vertical skeletal deviations. Thus, vertical overbite developed fairly similarly in the low and

high angle groups. Overdevelopment of anterior lower facial height in high angle groups was compensated by marked growth of the incisal heights of both jaws.

Beckmann and Segner (2002) studied the changes in alveolar morphology during open bite treatment. Dentoalveolar composition was studied in eighty-three open bite patients. Increases in overbite during treatment coincided with vertical lengthening of the symphysis, which exceeded increments in lower face height. They concluded that, in open bite, a dentoalveolar compensation mechanism resulted in a stable overbite at the end of treatment by enlarging symphysial height through a moderate increase in symphysial volume. In addition, retrusion of the maxillary incisors contributed to open bite reduction.

Etiology

According to Subtelny and Sakuda (1964), three etiologic factors were associated with open bite. The first was vertical growth deficiencies. These were always mentioned, although opinion differed with regard to the exact area reflecting the deficiency. Prior to a classic study by Hellman (1931), most authorities located the vertical deficiency in the anterior portion of the maxilla. The second was disproportionate muscle growth or aberrant muscle function. The enlarged or protrusive function of the tongue was thought to prevent the full eruption of anterior dental units or to exert a disfiguring influence on the

molding of the anterior dentoalveolar processes. The third was digit sucking habits. The authors stated that seldom will there be one single etiologic factor.

Mizrahi (1978) stated that anterior open bite, like any other malocclusion, was the result of certain causes either hereditary or non-hereditary origin and prenatal or postnatal in the tissues of the orofacial region. In the same way that horizontal skeletal dysplasias are inherited, so dysplasias in the vertical plane may also be inherited. Non-hereditary factors include thumb, finger or foreign body sucking, abnormal tongue function, trauma or pathology to the condyle, neurologic disturbances, and iatrogenic factors.

Worms et al. (1971) performed a twenty-year longitudinal evaluation of open bite of 1,408 Navajo children, ranging in age from 7-21 years. Open bite was defined as the absence of contact between the maxillary and mandibular incisors in centric relation. They concluded that a developmental factor, active in the mixed-dentition period, produced apparent spontaneous correction of 80% of the anterior or simple open bites. Therefore, early or interceptive treatment (cribs or retraining exercises) probably was of little or no value. This suggests that improvement in open bite as a clinical sign for evaluating therapy during this age period is a questionable strategy at best.

Finlay and Richardson (1995) studied 127 patients with open bite longitudinally for three years minimum using cephalometric radiographs. The open bite closed spontaneously in 50% of a prepuberal group aged between

7-10 years, in 49% of a puberal period aged 11-14 years, and in 44% of a post-puberal group aged between 14-21 years. Their figures for self-correction were lower than reported by Worms et al. and pointed to the need for some method of prediction as to which open bite cases might self-correct and which might not.

Nielsen (1991) reviewed the most common etiological factors of vertical malocclusion with special emphasis on the role of mandibular growth in the development of open bite and deep bite. He noted that patients with the so-called "long face syndrome" and a pronounced increase in lower face height had a more posteriorly directed growth pattern of the mandibular condyle. The direction of mandibular growth, as expressed at the chin, was mostly vertical. Anterior open bite was most commonly observed in this type of patient. They usually had little or no improvement in horizontal mandibular position over time. The associated dental eruption of the posterior teeth was generally vertical. The relative developmental differences of anterior facial height and posterior facial height also affected facial growth changes. These differences in height development led to rotational growth or positional changes of the mandible that influenced chin position. In instances where the increase in AFH was greater than in PFH, the mandible rotated posteriorly. This posterior growth rotation may have resulted in an anterior open bite, depending on the extent of vertical dentoalveolar compensation.

Kim and Nielsen (2002) evaluated condylar growth intensity, mandibular growth rotation and the association between growth intensity and rotation in thirty-two untreated subjects with class II malocclusion from ages 8-13. The average condylar growth intensity was two to three mm per year for boys and girls. Ninety percent of the subjects showed some degree of anterior or forward rotation; only one subject demonstrated posterior rotation. No clear relationship was found between amount of condylar growth and mandibular rotation. This indicated that untreated "growers" tended toward a reduction of a long faced syndrome based on the forward rotation that usually occurred.

Larsson (1987) reviewed the literature on malocclusion reported to be caused by prolonged sucking. He concluded that the finger sucking habit caused a reduction in alveolar growth. Usually, if the patient stopped the habit before the pubertal growth spurt, and if the lip function was normal, the open bite corrected by itself as a result of lip pressure. Another common finding was lengthening of the maxillary dental arch.

Willmot (1984) presented a case report of monzygotic twins aged 14 years; one sucked her thumb and one did not. The thumb sucker had a narrower upper arch and a more forward position of her premaxilla on cephalometric analysis with an increased overjet than the non-thumb sucker. Superimposed outlines of the tongue showed that the thumb sucker adopted a lower position of the dorsum of the tongue at the initial examination.

Speidel et al. (1972) considered the role of tongue function in anterior dental open bite. They observed that abnormal form elicits abnormal function, which may manifest itself as a compensatory function of the tongue and lips. An oral seal was required to swallow comfortably and efficiently. The patient with a backward-rotating growth pattern, an overbite of zero, and lips barely adequate to cover the teeth comfortably exhibited a morphologic configuration which required extreme activity of the tongue and mentalis muscle to effect a necessary circumoral seal during swallowing. If the patient's morphology required abnormal muscle activity, the activity was likely to enhance, rather than cause, the open bite tendency.

Linder-Aronson (1979) studied eighty-one mouth-breathing patients with hypertrophic adenoid vegetations where adenoidectomy was performed. These patients were compared with a similar number of control cases with the same sex and ages but without any nasal obstruction problems. A five-year follow-up study was carried out as well. Children who had difficulty in nasal breathing were characterized by increased lower and total facial heights, less sagittal depth of the bony nasopharynx, lower tongue positions, narrower upper arches, open bite tendency, retroclined upper and lower incisors, normal palatal vault height, and a posterior cross-bite tendency. After adenoidectomy, there was a normalization of the inclination of the upper and lower incisors, of the upper arch width, of the sagittal depth of the bony nasopharynx and of the inclination of the mandibular plane to the maxilla. The

results support the theory that disturbed nasal respiration can affect both facial morphology and the dentition.

Lowe (1980) documented enhanced genioglossus muscle activity together with an observed tongue protrusion, in response to jaw opening in adult subjects with anterior open bite. He found significant correlations between threshold muscle values and thirty-one cephalometric angular and linear variables. Low threshold values for the genioglossus muscle were correlated with negative overbites, undererupted maxillary and mandibular incisors, and low total face heights. Low threshold values for the masseter muscle were also associated with low overbite measurements. He concluded that this interdependence of tongue and jaw muscle activity and facial morphology suggested a contribution of the musculature to the development and/or maintenance of the dentition.

Woodside and Linder-Aronson (1986) noted that attempts have been made to establish a relationship between dentofacial deformities and nasopharyngeal airway inadequacies. Certain characteristic craniofacial morphologies may be associated with oral respiration resulting from an inadequate airway. They noted that we have yet to determine the critical levels of nasal obstruction that trigger the neuromuscular responses leading to mouth breathing. These triggers could be critical values of nasal resistance, lumen size, duration of insult, and age-related norms. They performed a longitudinal study of the lower anterior face heights of 107

Canadian females, who had complete annual records from 6-18 years of age. They assessed the size of the airway through the nasopharynx and the nasal cavity on lateral and posteroanterior cephalometric radiographs from 4-12 years of age. They demonstrated a difference in the incidence of reduced airway capacity between those with increasing lower face height and those with normal development of lower face height.

Trask et al. (1987) analyzed the effect of perennial allergic rhinitis on dental and facial skeletal characteristics. Twenty-five allergic children, who were apparent mouth breathers, were compared with their twenty-five siblings who did not have the disease and were apparent nose breathers, and fourteen nasal breathing control subjects were studied. The allergic subjects were characterized by deeper palatal height, retroclined mandibular incisors, increased total anterior facial height and lower facial height, a larger gonial angle, and greater SN, palatal, and occlusal planes to mandibular plane angles. Overall, the allergic children had longer, more retrusive faces than controls.

Bresolin et al. (1983) also studied mouth breathing in allergic children. They evaluated thirty chronically allergic mouth-breathing subjects and fifteen non-allergic nose breathers. They found that the upper anterior facial height and the total anterior facial height were significantly larger in the mouth breathers. Angular relationships of the SN, palatal and occlusal planes the

mandibular plane were greater in the mouth breathers. Overall, mouth breathers had longer faces with narrower maxillae and retrognathic jaws.

Ricketts (1968) described the classic clinical example of the relationship between airway obstruction and aberrant craniofacial growth as the patient with an "adenoid facies." These patients usually had an open mouth posture, nostrils that were small and poorly developed, short upper lip. Mouth breathing individuals have been described as possessing a narrow, v-shaped maxillary arch, high palatal vault, proclined upper incisors, and a class II dental relationship. McNamara (1981) supported Ricketts' findings and found that, on average, McNamara's study sample with airway obstruction was also characterized by excessive anterior facial height and a steep mandibular plane.

Vig (1998) noted that one of the problems in debating nasorespiratory obstruction and facial growth is the inability to provide unequivocal answers to such questions as: How much nasal obstruction is clinically significant? At what age is the onset critical and for how long does it have to exist before an effect on facial growth can be expected? She also questions the use of two-dimensional cephalometric radiographs to adequately assess adenoid size.

Van Spronsen et al. (1992) noted that long-face subjects had smaller maximum molar bite forces than do normal individuals. This has been attributed both to differences in moment arms and size of the jaw muscles. They compared the mid-belly cross-sectional areas of the jaw muscles of

thirteen long-faced and thirty-five normal adults by serial MRI scans. In the long-face group, the cross-sectional areas of the masseter, medial pterygoid and anterior temporal muscles were significantly smaller than in the control group. These results hint that differences in the sizes of the jaw muscles of long-faced and normal subjects might explain, in part, the observed differences in maximum molar bite force.

Harris and Johnson (1991) studied the heritability of craniometric and occlusal variables in a longitudinal sibling analysis. They did a serial assessment of untreated persons in thirty sib relationships from 4-20 years of age from the Bolton Brush Growth Studies of Cleveland, Ohio. Results defined a clear dichotomy; craniometric variables typically show significant additive components of variance. In contrast to craniometric variables, which have high heritabilities, almost all of the occlusal variability was acquired rather than inherited. This suggested that open bites of a predominantly skeletal nature had a large genetic component to their origin.

Yamagucchi et al. (2001) quantitatively evaluated the relationship between craniofacial morphology and the variant P561T in the growth hormone receptor gene (GHR) that is considered to be an important factor in craniofacial and skeletal growth. The subjects were unrelated individuals in a normal Japanese population and consisted of fifty men and fifty women. The normal Japanese population without the variant had a significantly greater mandibular ramus length (condylion-gonion) than those with the variant. This

suggests that this GHR variant may be associated with mandibular length growth. As open bite cases with a strong skeletal component tend to have shorter posterior face height (i.e., shorter ramus in many cases) than non-open-bite subjects, this certainly suggests a genetic impact on open bite.

Vertical Effect of Orthodontic Treatment

Creekmore (1967) reported on sixty-two untreated children. He found their lower molars growing vertically 1.59 mm over a period of 2½ years. Creekmore's paper included fifty non-extraction cases treated with fixed appliances. These cases had a 2.22 mm increase in lower molar height over the same 2½ year period. An increase in the posterior height of either the maxilla or mandible produced a backward rotation of the mandible. The author concluded that this increase would be detrimental in a patient with excessive anterior vertical dimension. Therefore, non-extraction treatment was probably not indicated in a patient with excessive anterior vertical dimension, as it seemed to lead to a backward rotation of the mandible.

Ricketts (1960) stated that the effect of class II intermaxillary elastics could be disastrous on some retrognathic cases due to an opening rotation (clockwise) of the mandible. Ricketts reported that, with the use of inter-arch elastics, the lower molar was elevated an average of 3.3 mm with a range up to 8 mm. His untreated control sample of one hundred growing patients with class I and class II occlusions with high mandibular plane angles had lower molars growing vertically 1.5 mm over a thirty month period.

Chua et al. (1993) examined the effects of extraction and nonextraction orthodontic treatment on the growth of the lower anterior face height (ANS-Me). A sample of 174 patients was divided equally into class I and class II cases, forty extraction and forty-seven nonextraction in each class. A linear cephalometric measurement from anterior nasal spine to menton was calculated for each case before and after treatment. Growth was factored out by normalizing ANS-Me measurements to the Michigan Growth Standard. The results showed that non-extraction treatment in both class I and class II subjects significantly increased the lower facial height and is associated with the downward, backward rotation of the mandible. Even with a longer average treatment time, extraction treatment was not related to any changes in lower anterior facial height.

Schudy (1964) described the vertical components of facial growth and recommended various treatment options. He advised that a hypodivergent facial pattern be treated with nonextraction and a hyperdivergent facial type be treated with extraction. He believed extraction of teeth closed the bite.

Treatment Options for Anterior Open Bite

Case Studies with Molar Extractions

Sandler et al. (2002) stated that there are many clinical situations in which extraction of first permanent molars should at least be considered. One of these situations was anterior open bite. He presented an eleven-year old male patient with a class III incisor relationship and anterior open bite who

was successfully treated with extraction of all four first molars. Cephalometric analysis near the end of treatment showed slight retroclination of the upper labial segment and retroclination of the upper labial segment that was necessary to close the anterior open bite. The mandibular plane angle had not increased during treatment although the lower anterior facial height proportion increased slightly.

Daugaard-Jensen (1973) presented case studies of first molar extractions for treatment of malocclusions among which were successfully treated anterior open bites. She noted that open bites usually closed spontaneously following extraction of first molars.

Williams (1979) stated that extraction of upper first molars also could play a favorable role in mild open bite class II, division I cases with good lower arch development. It avoided moving the upper first molar distally and consequently rotating the mandible down and back.

Brandt and Safirstein (1975) noted that in open bite treatment second premolar or first molar extractions afforded a better opportunity to accentuate the curve of Spee, thus preventing an increase in the anterior open bite. They noted several indications for four first molar removal. If the molars were carious, endodontically treated, multifilled, or when one molar had been extracted, the remaining ones may be extracted for symmetry. A final consideration was facial esthetics. If patients had large chin buttons and/or large noses and the removal of the first premolars may result in a concave

profile, consideration should be given to removal of the four first molars. The rationale here was that the farther back in the arch the extractions were done, the less facial change would result.

Arvystas (1977) published a case study wherein a skeletal open bite was successfully treated in a sixteen-year old adolescent girl with the extraction of all four permanent first molars. The patient presented with a high mandibular plane angle, severe open bite and a class II crowded malocclusion. The molar extraction space was used to align and relieve the crowding of the anterior teeth. Any remaining extraction space was closed by mesial movement of the second molars. Arvystas stated that this aided in the closure of the open bite, with a resultant counterclockwise rotation of the mandible.

Cooke and Newsome (1990) presented a case study of a twelve-year old girl with a class I malocclusion involving extraction of all four permanent first molars to correct her severe skeletal anterior open bite. Only the second permanent molars were in contact when the teeth were in occlusion. After the first molar extractions, the permanent second molars began to move forward and the open bite began to close. In addition to this treatment technique of removing teeth from the wedge, it had been planned to use chin cup therapy with the application of vertical pulling force to close the bite, but this proved to be unnecessary. The authors noted that three years post-retention, the lower facial height was reduced and the mandible rotated counterclockwise. Most

stable was the counterclockwise upward rotation of the occlusal plane of the mandibular arch.

Aras (2002) assessed the vertical changes occurring in skeletal open bite patients treated orthodontically with different extraction patterns. Fifteen patients with anterior open bite only were treated with first premolar extractions. Seventeen patients with an open bite extending to the posterior teeth were grouped according to whether second premolars or first molars were extracted. He found that, generally, within the appropriate indications, extraction of the second premolars or the first molars led to a closing rotation of the mandible in subjects with a skeletal anterior open bite extending to the posterior teeth.

Ortial (1995) addressed the vertical dimension and the therapeutic choices available. He used a sample of 323 patient records to examine variations in the vertical skeletal pattern. His sample had 51% with a moderate FMA, 26% with a skeletal deep bite (low FMA) and 23% exhibited a skeletal open bite pattern (high FMA). He used a variety of extraction patterns depending on the severity and type of malocclusion. In one case illustrative of his approach to class II skeletal open bite, he recommended premolar extraction to close the bite along with first molar extraction to correct the molar relationship. He considered a genioplasty a necessary component of treatment of the open bite pattern to correct the excess vertical dimension and improve the profile.

Kim (1974) recommended the extraction of second molars to correct open bite thru the elimination of the wedging effect in the posterior portion of the dentition. He reported a case of a 16-year old boy with an 11 mm anterior open bite who had been treated with tongue crib therapy unsuccessfully. Kim diagnosed the problem as skeletal and extracted four premolars to eliminate some crowding and improve incisal axial inclinations. The second molars were removed to eliminate the wedging effect of the posterior dentition. He noted that, in patients with anterior open bites, the upward sloping palatal planes relative to the mandibular plane caused the maxillary second molar to have a wedging effect on the occlusal plane.

However, Richardson and Richardson (1993) compared changes in incisor overbite in thirty-three subjects, who had four second molars extracted, with thirty-three untreated subjects. There was an average increase in overbite of 0.7 mm in the extraction group, significantly different from an average decrease of 0.8 mm in the control group. But, the tendency to increase in overbite was greater in subjects whose presenting overbite was already reduced. The mechanism responsible for overbite reduction appeared to be a slight distal movement of the dentition, with retroclination of incisors and increase in inter-incisal angle.

Vaden (1998) published a case report of an adolescent boy with class II division 1 malocclusion with horizontal and vertical discrepancy with FMA of 30° and excessive anterior facial height. He extracted all four first premolars

to correct crowding and reduce the overjet. However, he then extracted maxillary first molars to correct the class II molar relationship. The FMA reduced by 4° after the first molar extractions. Extraction of the first molars allowed the mandible to autorotate. Vaden noted that, with this patient, 5 mm of mandibular molar extrusion occurred. However, compensatory growth in a favorable direction negated much of the unfavorable effect of the mandibular molar extrusion.

In class II open bite, Sassouni and Nanda (1964) stated that the treatment strategy involved rotating the mandible in a closing rotation and lowering the premaxilla but not the posterior half of the palate. All forces that would tend to extrude the molars should be avoided. These cases call for reduction of tooth material. In the most severe cases, Sassouni and Nanda recommended the extraction of eight permanent teeth to accomplish bite closure, including maxillary first molars and mandibular molars and four first premolars.

Elham et al. (2000) did a cephalometric study of the effect of extraction of lower first permanent molars. The sample consisted of twenty-eight patients with an age range of 8-14 years. A cephalometric radiograph was taken prior to the extraction and after a mean of eighteen months. No other treatment was done during the observation period. On average there was no change in the angulation of the incisors to the bases. There was no significant change in the vertical relations of the jaws, save that caused by

normal growth and development. A significant correlation was found between the change in overbite and original overbite. The extraction of the lower first molars resulted in deepening of the overbite on average, but no effect on the anterior facial height or any other vertical relationship was noted. Increased overbite was associated with lingual positioning of the lower incisor and the change in facial proportions.

Cephalometric Studies with and without Extraction of Biscuspid Teeth with Control Groups

Kocaderelli (1999) studied the effect of first premolar extraction on vertical dimension. The author compared the vertical changes occurring in class I patients treated orthodontically with first premolar extraction and compared those changes occurring in class I patients treated orthodontically without extractions. Six linear and eight angular measurements were utilized from the lateral cephalograms. The author found that the vertical changes occurring after the extraction of maxillary and mandibular first premolars were not different than those occurring in the non-extraction cases.

Garlington and Logan (1990) studied the records of twenty-three Angle class II division 1 patients who underwent mandibular second premolar enucleation in the early mixed dentition. Maxillary first premolars were extracted as well. The patients were selected at random from a group which had mandibular plane angles in excess of 38° to SN. They concluded that lower face height was reduced in the treated cases because of a mean 0.8° forward rotation of the mandible due primarily to a relative decrease in lower

posterior alveolar growth. They postulated that the lower posterior alveolar growth might have been caused by the 0.8 mm mesial drift of mandibular first molars. Total face height did not decrease, indicating possible compensatory changes in maxillary growth.

Staggers (1990) studied the treatment results of maxillary and mandibular second molar extraction cases and compared them with treatment results of maxillary and mandibular first premolar extractions cases. She observed no statistically significant difference in the mean change of the mandibular plane angle between the two groups. No change was observed in that angle in the second molar extraction group and a -0.5° change was noted in the first premolar group. A statistically significant difference was noted in the vertical position of the incisors. The first premolar extraction group demonstrated more uprighting than the second molar group.

Staggers (1994) investigated the claim that the extraction of first premolars causes a decrease in the vertical dimension of occlusion. She compared forty-five class I non-extraction cases and thirty-eight class 1, first premolar extraction cases. No significant differences were found between the vertical changes occurring in the extraction and non-extraction groups. On average, orthodontic treatment in both groups produced an increase in the cephalometric vertical dimensions that were examined.

Cusimano et al. (1993) designed a study to investigate the change in MPA in high-angle patients treated with the extraction of four first bicuspids

and protraction of the posterior teeth. They studied pre-treatment and post-treatment cephalograms of thirty-seven adolescent patients with MPA relative to cranial base (SN-Go GN) of 36° or better with class I or class II occlusion and four first bicuspid extractions. They concluded that mesial molar movement was to be expected in first bicuspid extraction cases and accounted for the belief that facial height should decrease. However, their results showed 3.2 mm of upper molar extrusion and 2.2 mm of lower molar extrusion. As much as 1.9 mm of this vertical movement of the maxillary molar and 1.6 mm of that of the mandibular molar was attributed to growth. The occlusal movement of the posterior teeth tended to keep pace with the increase in anterior facial height, thus maintaining the MPA and nullifying the bite-closing effect of posterior protraction.

Dietrich (1992), in his Masters Thesis at Case Western University, studied the vertical correction of open bite malocclusion in patients who had been treated with four first bicuspid extractions and fixed edgewise appliances. His thirty-one cases were selected on the basis of zero vertical incisor overlap and no incisor contact at the start of treatment. The treated group was matched by age, sex and treatment time with a sample of untreated open bite patients from the Broadbent Bolton Collection, Cleveland, Ohio. Mean treatment time was forty months. Dietrich observed that most of the open bite correction was achieved by lingual tipping of the upper and lower incisors. Lower facial height and mandibular plane increased slightly,

having a negative effect on open bite correction. There was no difference in the vertical position of the maxilla. The gonial angle decreased. The mandibular skeletal increase was attributed to extrusion of the buccal segments. Patients with open bite malocclusion exhibited obtuse gonial angles and higher mandibular plane angles.

Additional Treatment Approaches

Kim et al. (2000) performed an analysis of the pretreatment and post-treatment cephalometric radiographs of twenty-nine growing and twenty-six non-growing patients. Multiloop edgewise archwire (MEAW) therapy was used. Lateral cephalograms were analyzed for skeletal, esthetic and dentoalveolar changes. The overbite increased an average of 4 mm in both groups. The change in overbite during the two-year follow-up period was not significant.

Chang et al. (1999) looked more closely at what treatment changes contributed to the open bite correction with the MEAW technique using sixteen young adults. Treatment changes were observed mainly in the dentoalveolar region in the upper and lower occlusal planes, accompanied by the uprighting of the posterior teeth through the distal tipping movement of the entire dentition. Chang et al. (1999) concluded that the treatment changes of open bite malocclusion by the MEAW were similar to those found in the natural dentoalveolar compensatory mechanism.

Alexander (1999) presented a case report in which a twenty-one year old female patient with a class I malocclusion, a 4 mm anterior open bite and vertical skeletal discrepancy was treated. There was a significant anteroposterior discrepancy as well. First premolar extractions in conjunction with tongue therapy and high pull headgear were successfully employed. High-pull headgear, unusual for an adult, was used to help control extrusion of posterior teeth. Stability of the correction of the anterior open bite was observed four years post-treatment.

Fränkel and Fränkel (1983) emphasized the role of the orofacial musculature in maintaining the positional relationship that ensures a functionally adequate volume of the oral, nasal, and pharyngeal spaces. Fränkel observed that in the treatment of skeletal open bite there is a need for the use of the function regulator combined with lip seal training. Long-term post-retention follow-up study showed that relapse occurred in all treated cases unless a competent anterior oral seal had been achieved, regardless of whether posterior teeth had been removed.

Fränkel and Fränkel (1986) stated that, on the basis of extensive clinical experience, it appeared to be irrational to assume that molar extraction spontaneously results in an autorotation of the mandible with a permanent closure of the anterior open bite. They believed that molar extraction constituted a change only of the rotation center along the occlusal plane anteriorly, with only a small increase in the interocclusal clearance. It

did not cause a compensatory neuromuscular adaptation. Therefore if molar extraction was performed alone without lip seal training, long term stability of open bite correction would fail.

Epker and Fish (1977) discussed the basic treatment approaches to open bite, which included both basic orthodontic approaches and basic surgical approaches.

The basic orthodontic approaches were subdivided into (1) redirection of growth, (2) tooth movement, and (3) habit control.

1. Redirection of growth. This is the treatment of choice in rapidly growing patients with mild open-bite deformity. Three types of appliances:

    a. HPHG directed to posterior maxilla

    b. Chin cup with high-pull forces

    c. The activator and Bimler appliances.

    These appliances were all intended to inhibit vertical growth in the posterior maxilla so that the anterior alveolar development could "catch up" and close the bite. The basic underlying theory was the overdevelopment of the posterior maxillary alveolus.

2. Tooth movement. This was of a vertical nature and could be divided into two types:

    a. Intrusion of teeth which were in occlusion

    b. Extrusion of teeth at the open bite site

3. Habit control. Three principal methods-tongue crib, speech and swallowing therapy and myofunctional therapy.

Epker and Fish (1977) said that treatment of open bite by orthodontic means seldom involved only one of the above methods but most often utilized a combination of them. For instance, speech therapy to correct a "tongue habit," HPHG to redirect growth, extractions, and vertical elastics in the anterior region are some methods. The basic surgical approaches include surgery in the anterior maxilla and mandible, posterior maxilla, simultaneous anterior and posterior maxilla, mandibular body and ascending ramus.

Haas (1980) reported clinical success with skeletal open bite and the hyperdivergent facial types with artificial application of anterior muscular-like force to intrude posterior teeth, interfering with posterior alveolar growth, preventing the descent of the maxilla, moving it superiorly and perhaps even changing mandibular morphology by redirecting growth. Depending on the degree of hyperdivergence, as indicated by Frankfort-Mandibular Plane Angle, he recommended different types of extraoral force-facebow and occipital anchorage for mild vertical dysplasia, cervical gear for moderate vertical jaw problems (FMA 30° to 35°), and when maximum vertical orthopedic correction was desired (FMA greater than 35°), a vertical chin cup force.

Bazzucchi (1999) studied the correction of open bite in two phase treatment with the use of the Active Vertical Corrector, a magnet based intraoral intrusion device. His twenty-nine cases were obtained from one orthodontist on the basis of lack of vertical incisor contact at the start of

treatment. Each subject was matched by age, sex and treatment time with an untreated subject from the Broadbent Bolton Collection of Cleveland, Ohio. Mean treatment time was fifty months. Most of the clinically significant open bite correction during treatment with the Active Vertical Corrector during Phase 1 was achieved by relative decrease of the mandibular skeletal height and lingual tipping of the upper and lower incisors. During Phase 2, extrusion of the upper and lower incisors was clinically significant for correction of anterior open bite.

The active vertical corrector (AVC), i.e., cobalt-samarium repelling magnets, has been used and studied by Dellinger (1996), Kiliaridis (1990), and Barbre (1991) in the treatment of skeletal anterior open bite. They all reported closure of the anterior open bite with this device. The studies were divided as to the nature of the correction-whether it occurred by posterior intrusion or incisor changes.

Pearson (1978) has reported success in the vertical control of the facial skeleton in patients with backward-rotational growth tendencies and anterior open bites. He has found the use of the vertical chin cup to be very effective.

Sankey et al. (2000) performed a cephalometric study to evaluate an early non-extraction treatment approach for patients with severe vertical skeletal dysplasia and maxillary transverse constriction. Thirty-eight patients, mean 8.2 years of age, were treated with lip seal exercises, a bonded palatal

expander appliance and a banded lower Crozat/lip bumper. Patients with poor masticatory muscle force wore a high-pull chincup 12-14 hours per day. A control group was matched for age, sex and mandibular plane angle. They observed that treatment significantly enhanced condylar growth, altered it to a more anterosuperior direction, and produced forward mandibular rotation 2.7 times greater than control values. Posterior facial height increased significantly more in treated patients and the maxillary molars showed relative intrusion. The sixteen patients with open bite malocclusion exhibited a 2.7 mm increase in overbite and inhibition of growth in anterior lower facial height.

Hotokezaka et al. (2001) treated a twenty-one year old woman with a dental open bite malocclusion with standard edgewise appliance and retention with a tongue crib and upper Begg-type plate retainer to suppress the tongue thrust and fixed lower retainer. During retention, there was considerable relapse with widening of the lower intermolar distance, flaring of the anterior teeth and increased mobility. A tongue reduction was employed with one-third of the middle dorsal part of the tongue excised. After six months, the relapse had all but disappeared. No appliances were used after surgery.

Huang (2002) recently reviewed the orthodontic literature with respect to treatment success and long-term stability after orthodontic or combined orthodontic-surgical treatment of anterior open bite. He looked at six studies assessing orthodontic therapy alone and fifteen studies evaluating the

combined orthodontic-surgical therapy. The studies ranged from case series to cohorts to consecutively treated cases. He further analyzed those studies in which long-term stability had been evaluated and reported. He reported that the cumulative results of those studies indicated that approximately 80% of anterior open bite subjects had positive overlap at last follow-up, whether they underent only orthodontic therapy or a combination of orthodontic-orthognathic therapy. Orthodontic therapies appeared to have slightly lower treatment success but better stability than surgical therapy. The few non-surgical studies were case series, with relatively small samples and the potential for selection bias. The surgical studies consisted of case studies and cohort studies. He believed that the surgical studies proved a higher level of evidence than the orthodontic studies based on their greater numbers, the case series that report on consecutively treated subjects and a very large multi-center study involving 267 subjects in a cohort study.

STATEMENT OF THESIS

The primary purpose of this investigation is to test the "wedge hypothesis," i.e., does removal of first molar teeth from the wedge result in reduced anterior facial height subsequent to orthodontic treatment?

MATERIALS AND METHODS

The Treated Group sample consisted of thirty subjects who had orthodontic treatment in conjunction with having their permanent mandibular and maxillary first molars extracted. These subjects were provided by ten different orthodontists. The sample selection occurred in the following manner.

Letters were sent to all members of the Cleveland Society of Othodontists and to orthodontic clinicians known to treat with extraction of first molars according to the literature (Drs. Kesling (1988), McLaughlin (2001) and Sandler (2002)). Additionally, e-mail was sent to the members of the Electronic Study Club for Orthodontists. The letters and e-mails requested cases that met the following inclusion criteria:

1. Pre-treatment and post-treatment cephalograms of diagnostic quality
2. Extraction of all four first permanent molars
3. Full upper and lower fixed orthodontic appliance treatment

These data collection methods yielded a total of seventy-two cases. Forty-five of these cases met the inclusion criteria according to the lead investigator. These forty-five cases were then sorted by SN-Mandibular plane (high to low) and overbite (minimum to maximum).

The final treatment sample used for analysis consisted of thirty patients who had full fixed appliance orthodontic treatment with extraction of all four permanent first molars. Ten orthodontists contributed cases to this final sample.

Thirty untreated controls matched on the basis of age and gender were selected from the Bolton Collection, Cleveland, Ohio.

Cephalometric Analysis

The two groups of pre-treatment and post-treatment radiographs were traced on 0.003" matte acetate with a 0.5 mm mechanical pencil. For statistical comparison, a cephalometric analysis was utilized which contained six linear and two angular measurements (Kishiyama 1987) (see Figure 1). Linear measurements were made to the nearest 0.1 mm using a Fowler "Max-Cal" electronic digital caliper. Angular measurements were made to the nearest 0.5° with a Maisel orthodontic template.

The Kishiyama cephalometric analysis was used to evaluate dental and skeletal changes from time one to time two for both the Treated and the Control Groups. This analysis enabled the investigator to separate bodily movements of the upper and lower incisors from tipping movements (see Figure 2). Bilateral anatomic landmarks were bisected and the midpoints calculated. This reduced landmarks to their midsagittal value allowing identification of fifteen points according to Parker (1990).

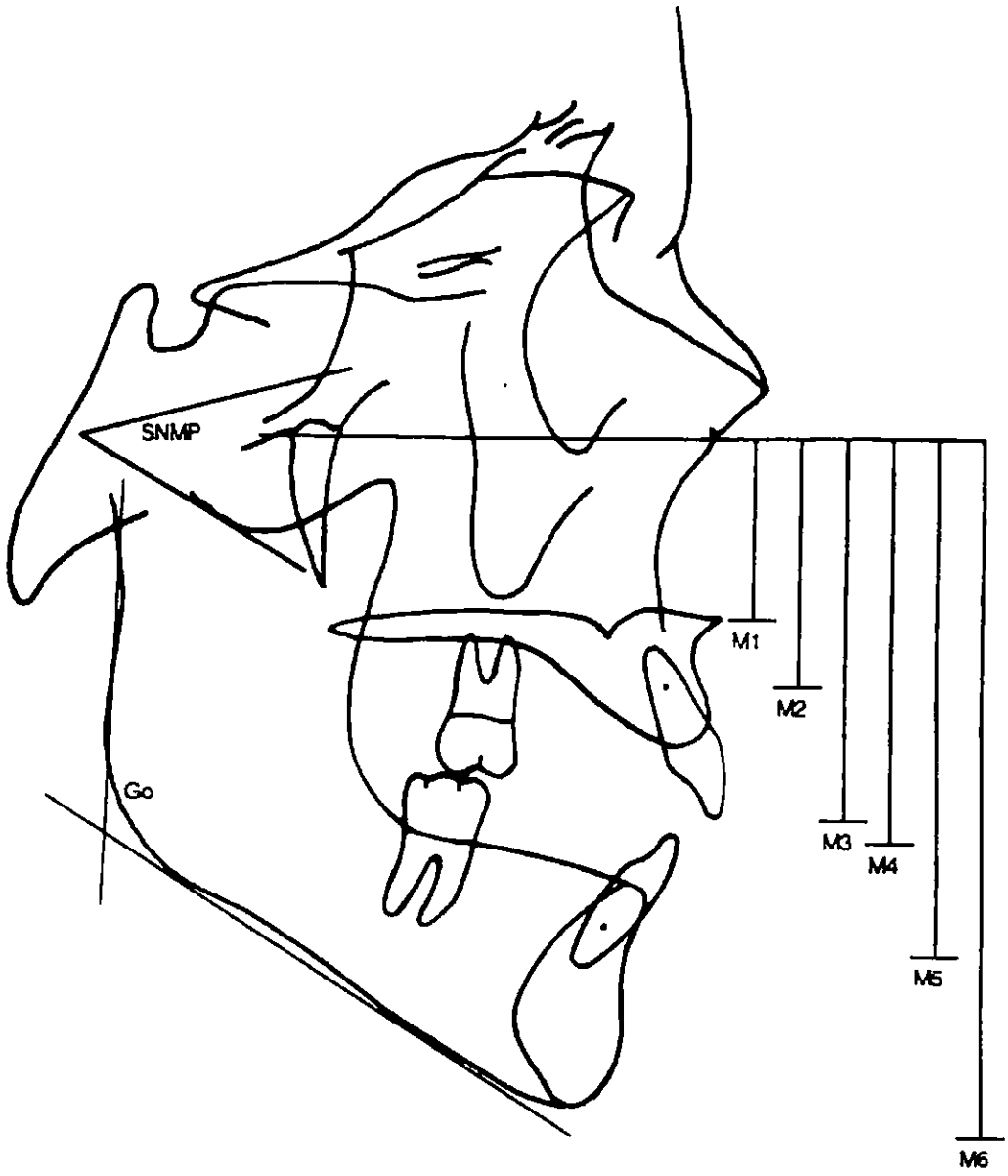


Figure 1. Measurements used to derive variables. See explanation of M_1 through M_6 on pages 48-49.

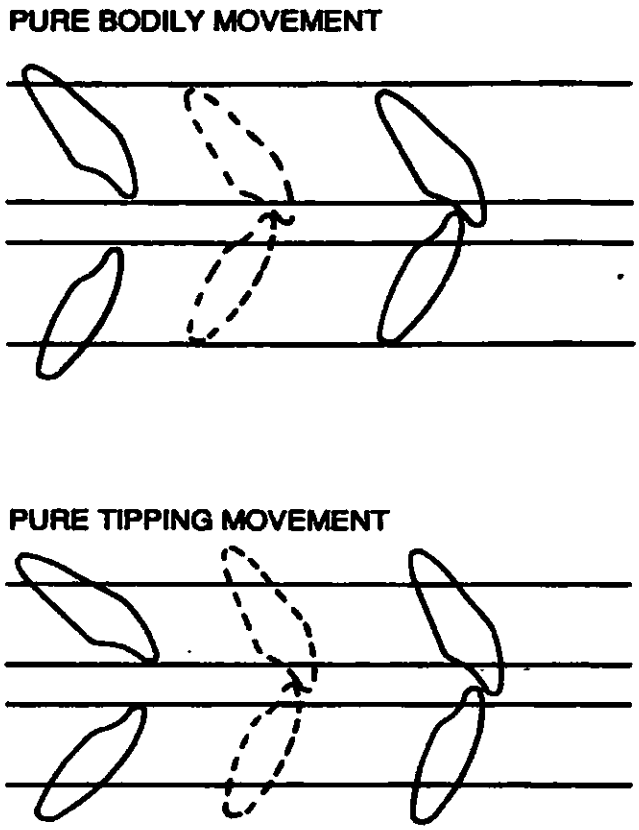


Figure 2. Bodily versus tipping movements of incisors for open bite correction. Note in the tipping movement the open bite correction occurs by the uprighting of the teeth-i.e., the angulation changes. In the bodily movement, correction occurs by extrusion of the teeth.

The landmarks traced were:

1. Sphenoethmoidal junction (SE)
2. Foramen rotundum in the pterygomaxillary fissure[1]
3. Inferior-most point of the pterygomaxillary fissure
4. Three mm above orbitale[1]
5. Posterior nasal spine (PNS)
6. Anterior nasal spine (ANS)
7. Center of resistance (CR) of the upper incisor
8. Incisal edge of the upper incisor
9. Incisal Edge of the Lower Incisor
10. Center of resistance (CR) of the lower incisor
11. Articulaire (AR)
12. Gonion (GO)
13. Menton (ME)
14. Sella
15. Nasion

All landmarks were traced for the Treated group at time 1(T1), Treated group at time 2 (T2), Control group at time 1 (C1), and Control group at time 2 (C2) with the exception of the upper and lower incisors and the horizontal reference line. According to Liu and Herschleb (1981), the CR for the incisors was arbitrarily set at 40% of the distance from the root apex to the alveolar

[1] Used to construct the horizontal reference line (HRL) on the time one tracing and transferred to the time two tracing by superimposition on anterior cranial base landmarks

crest on the Time 1 radiograph for both Control and Treated. A template was used to transfer the CR point from the Time 1 to Time 2 tracings (Liu and Herschleb 1981). A digital caliper was used to measure this distance accurately to the nearest 0.1 mm. This was marked on the long axis of each incisor at T1. The CR of the upper and lower incisors was transferred to the T2 tracings by registration on the incisal edge.

The sphenoethmoidal junctions and the anterior cranial bases were superimposed to evaluate anatomic change from Time One to Time Two for both Control and Treated Groups. After landmarks were traced, the horizontal reference line (HRL) was constructed as described by Baumrind (Baumrind and Miller 1980). With superimposition of the Time Two radiograph on the sphenoethmoidal junction and the anterior cranial base the horizontal reference line from the T1 tracing was transferred to the T2 tracing (Fiducial method).

Linear measurements in the anterior vertical analysis were represented by the following abbreviations (see Figure 1):

Measurement one (M_1):	distance from the horizontal reference line to ANS
Measurement two (M_2):	distance from horizontal reference line to center of resistance of the maxillary incisor.
Measurement three (M_3):	distance from HRL to incisal edge of upper incisor

Measurement four (M_4): distance from the reference line to the incisal edge of the mandibular incisor

Measurement five (M_5): distance from HRL to center of resistance of mandibular incisor

Measurement six (M_6): distance from HRL to Menton (Me).

These six linear measurements produced seven variables used to assess anterior vertical changes. These variables are described as follows (see Figure 3):

1. Maxillary skeletal change (MXSK) evaluated by change in M_1
2. Bodily movement of the maxillary incisor (BUI) evaluated by subtracting M_1 from M_2
3. Tipping movements of maxillary incisor (TUI)-evaluated by subtracting M_2 from M_3
4. Bodily movement of the mandibular incisor(BLI)-evaluated by subtracting M_5 from M_6
5. Tipping movements of the mandibular incisor (TLI)-evaluated by subtracting M_4 from M_5.
6. Mandibular skeletal change (MNSK)-evaluated by subtracting M_1 from M_6
7. Change in overbite (OB)-evaluated by subtracting M_4 from M_3.

Angular Measurements

The mandible (MNSK) measurement includes the factors which effect the displacement and vertical position of the mandible. Changes in the mandibular plane angle, as well as in the gonial angle, influence the magnitude of change of MNSK. By measuring the difference in the angle

formed by the intersection of the mandibular plane (Gonion-Menton) with the sella-nasion plane, the changes in the mandibular plane angle from Time 1 to Time 2 were compared.

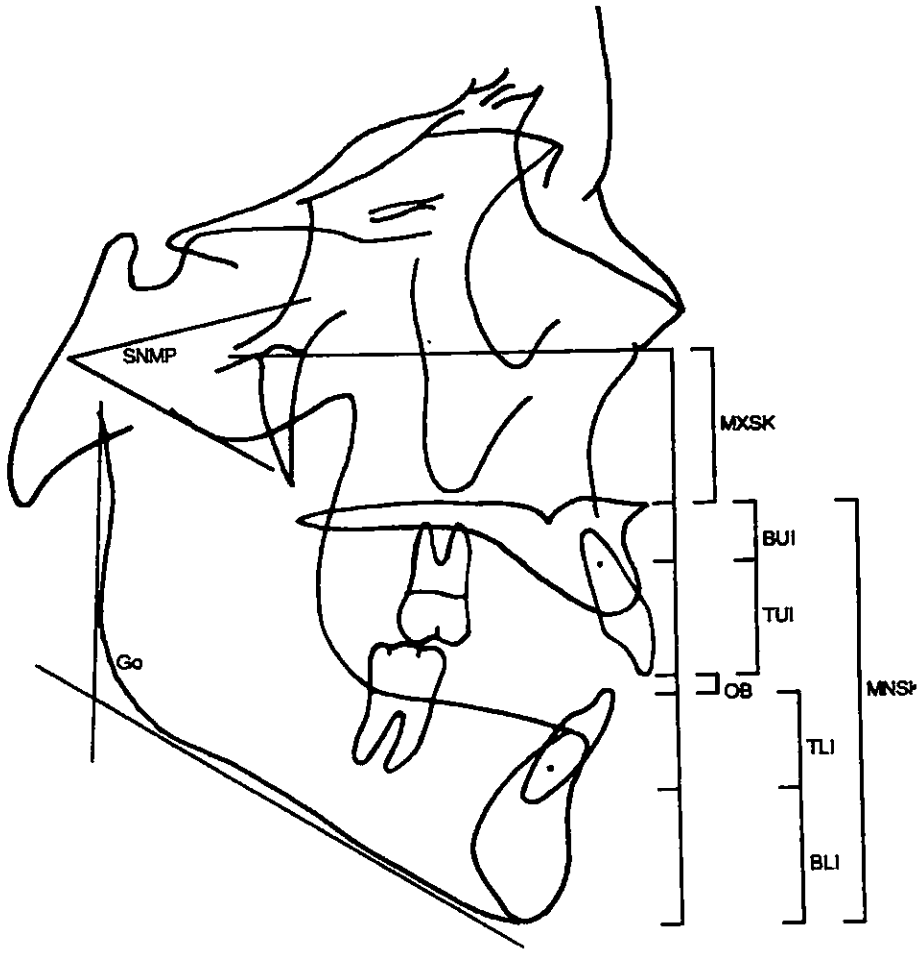


Figure 3: Cephalometric tracing showing the seven linear and two angular variables used in the vertical analysis. MNSK will be less in the treatment group if the "wedge hypothesis" is true. See explanation of variables on page 51.

Convention of Signs

Dental and skeletal responses associated with a vertical increase of incisor overlap were represented by a positive sign. A negative sign was given to those responses associated with vertical decrease of overlap. Stated simply, a negative sign was given to dental and skeletal movements away from the occlusal plane, while movements towards the occlusal plane were given a positive sign (Bazzucchi 1996).

Variable: MXSK
- \+ Downward movement of anterior aspect of maxilla
- \- Upward movement of anterior aspect of maxilla

Variable: BUI
- \+ Upper incisor extrusion relative to ANS
- \- Upper incisor intrusion relative to ANS

Variable: TUI
- \+ Uprighting of upper incisor
- \- Labial tipping of upper incisor

Variable: TLI
- \+ Uprighting of lower incisor
- \- Labial tipping of lower incisor

Variable: BLI
- \+ Lower incisor extrusion relative to menton
- \- Lower incisor intrusion relative to menton

Variable: MNSK
- \+ Upward movement of menton relative to ANS
- \- Downward movement of menton relative to ANS

Variable: OB
- \+ Overbite increased
- \- Overbite decreased

Statistical Analysis

All data were analyzed in the Orthodontic Department at Case Western Reserve University utilizing the SPSS/PC statistical program. For each of the seven linear variables and two angular variables examined, the mean and standard deviation was calculated for both the Treated and Control groups. In comparing the mean difference between the Treated and Control Groups, a two sample t-test was used. For the comparison between pre-treatment and post-treatment (Time 1 and Time2) for the Treated group, a paired t-test was utilized. Similarly, a paired t-test was utilized for comparison between Time 1 and Time 2 for the Control group (C1 and C2). A p-value of 0.05 was used to assign statistical significance.

Error Assessment

To evaluate the degree of investigator measurement error, twenty-four radiographs were randomly selected and measurements for the seven linear and two angular variables utilized in this study were repeated. The second set of measurements was compared to the first set using intraclass correlation coefficients.

Tracing error was evaluated in a similar manner. Twenty-four radiographs were retraced by the investigator and cephalometric analysis repeated on those tracings. The calculations for the seven linear and two angular variables were compared for the first and second set of tracings using intraclass correlation coefficients.

RESULTS

Patient Sample Description

The Treated Group consisted of thirty subjects that had all four first molars extracted and subsequent orthodontic treatment. The original Control Group consisted of thirty untreated subjects. Five controls were later found to have had a lower holding arch placed and therefore were "treated." These subjects were then removed from the control sample. The final Control sample that was used in this analysis consisted of twenty-five untreated subjects from the Bolton Brush Growth Study Center whose average initial age and length of observation were comparable to the Treated group. To test statistical significance between Treated and Control groups, the 2-sample t-test was employed. Paired t-test was used when comparing Time 1 and Time 2 for the Treated and Control groups on an intragroup basis. Descriptive statistics, including the means, standard deviations, and ranges where appropriate, are listed for reference. The treated group contained a total of eighteen females and twelve males (see Table 1). The control group consisted of fifteen females and ten males. The mean age of the Control group at Time 1 was 12.5 years, while the Treated group was 12.4 years. The average time interval between initial and final radiographs for both the Control and Treated groups was thirty-eight months.

TABLE 1.–Comparison Between the Control and the Treated Groups

	CONTROL	TREATED
TOTAL SAMPLES	25	30
FEMALES	15	18
MALES	10	12
AGE: TIME 1	12y5m ± 2y7m	12y4m ± 2y6m
AGE: TIME 2	15y7m ± 2y3m	15y6m ± 2y2m
TIME 1 TO TIME 2	38m ± 17m	38m ± 18m

Control Versus Treated Group at Time 1

There were three variables that were significantly different ($p < 0.05$) when comparing the initial radiographs of both groups (see Table 2). The

TABLE 2.– Comparison Between Control and Treated Groups at T1

VARIABLE	CONTROL		TREATED		P-VALUE
	MEAN	± STD	MEAN	± STD	
MXSK	23.9	± 4.6	24.4	± 3.5	0.64
BUI	8.6	± 2.4	8.9	± 3.1	0.65
TUI	18.8	± 1.4	18.8	± 2.0	0.993
TLI	15.7	± 1.6	16.4	± 1.4	0.094
BLI	21	± 2.8	22.2	± 3.1	0.133
MNSK	60.1	± 4.7	64.1	± 5.6	0.006*
OB	4	± 1.6	2.2	± 1.7	0.000*
GO	129.3	± 4.7	132.9	± 5.8	0.009*
MPA	35.3	± 3.7	36.9	± 8.0	0.363

*significant p<0.05

mean values for gonial angle and MNSK were significantly greater and the overbite was significantly less in the Treated Group as compared to the Control Group. The gonial angle was 3.6° larger and the lower anterior facial

height (MNSK) was 4.0 mm greater in the Treated Group at T1 versus the Control Group. Overbite was 1.8 mm less in the Treated Group at T1.

The Control Group

The Control Group showed significant changes in four variables from Time 1 to Time 2 (see Table 3). There was an increase in the height of the

TABLE 3.--Comparison between Time 1 and Time 2 for the Control and Treated Groups

	CONTROL T1		CONTROL T2		P-VALUE	TREATED T1		TREATED T2		P-VALUE
	MEAN	±STD	MEAN	±STD		MEAN	±STD	MEAN	±STD	
MXSK	23.9	± 4.6	25.9	± 4.4	0.000*	24.4	± 3.6	26.9	± 4.7	0.000*
BUI	8.6	± 2.4	9.7	± 2.9	0.004*	8.9	± 3.1	10.3	± 2.8	0.000*
TUI	18.7	± 1.4	18.8	± 1.9	0.804	18.8	± 2.0	19.2	± 1.5	0.089
TLI	15.7	± 1.6	15.8	± 1.6	0.58	16.4	± 1.4	16.6	± 1.4	0.484
BLI	21	± 2.8	23.3	± 3.4	0.000*	22.2	± 3.1	24.5	± 3.5	0.000*
MNSK	60.1	± 4.7	63.6	± 5.7	0.000*	64.1	± 5.6	67.7	± 6.5	0.000*
OB	4	± 1.6	4.1	± 2.0	0.787	2.2	± 1.7	2.9	± 1.3	0.076
GO	129	± 4.2	128.4	± 4.8	0.152	132.8	± 5.7	132.3	± 6.6	0.485
MPA	35.3	± 3.7	35.2	± 4.2	0.7	36.9	± 8.0	36.4	± 7.8	0.233

*significant $p<0.05$

maxilla (MXSK) of 2 mm. Concurrently, the upper incisor measurement showed extrusion of 1.1 mm. Similarly, the anterior mandibular skeletal height increased by a mean of 3.5 mm (MNSK) while the lower incisors extruded 2.2 mm. during the observation period (BUI).

The Control Group showed 0.1 mm of bite closure during the thirty-eight months between initial and final radiographs (see Table 5 and Figure 4). The mean values for variables MXSK, BUI, TUI, TLI, BLI, SN-MP and Go all

moved in a positive direction for anterior overbite increase. The mean value for MNSK had a negative effect on overbite increase.

Values for this group of control subjects were also compared to the values from the Control Groups used by Dietrich (1992), Damon (1995) and Bazzucchi (1996). The average per year change for each study's control group is shown in Table 4. There were no clinically significant differences in the changes noted among all control groups. All measurements contributed to a positive increase in overbite except for mandibular skeletal height which increased on average for all four groups.

TABLE 4. – Comparison between the changes per year for the Control Groups in the Current Investigation, Damon's 1995 Study, Dietrich's 1992 study and Bazzucchi's 1996 study

VARIABLE	DIETRICH 1992 CONTROL MEAN VALUE	BAZZUCCHI 1996 CONTROL MEAN VALUE	DAMON 1995 CONTROL MEAN VALUE	GROISSER 2002 CONTROL MEAN VALUE
MXSK	0.7	0.8	0.7	0.6
BUI	0.3	0.5	0.5	0.3
TUI	0	0	0	0
TLI	0	0	0	0
BLI	0.6	0.6	0.6	0.7
MNSK	-0.8	-1.2	-1.1	-1.1
OB	0.1	0.2	0	0.2
GO	0.4	0.1	0.6	0.1
MPA	0.2	0.1	0.3	0.1

The Treated Group

Four variables were significantly different in the Treated Group between Time 1 and Time 2 (see Table 3). The maxillary skeletal height (MXSK) increased by 2.5 mm during the observation period. Concurrently, the upper incisors extruded (BUI) by 1.4 mm, which would tend to increase the overbite. Similarly in the lower jaw, the mandibular skeletal height (MNSK) increased by 3.5 mm, which would tend to decrease the overbite. However, this was offset by the extrusion (2.3 mm) of the lower incisors (BLI), during the same time period.

The Treated Group showed 0.7 mm of bite closure (OB) during the thirty-eight months between initial and final radiographs (see Table 3 and Figure 4). The mean values for the variable TUI, TLI, Go and SN-MP all moved in a positive direction for anterior overbite closure.

Control Versus Treated Group From Time 1 to Time 2

There were some clinically notable results when comparing the mean changes in treated versus control groups from Time 1 to Time 2 (see Table 5 and Figure 4). The Treated Group did show a greater increase in overbite (by 0.6 mm) than the controls. Positive contributions to this result came from extrusion and tipping of the upper and lower incisors (BUI, BLI, TUI, TLI) as well as the slightly greater decrease in the Mandibular Plane Angle (MPA) in the Treated Group.

TABLE 5. – Comparison of the Changes from T1 to T2 between the Control and Treated Groups

VARIABLE	CONTROL		TREATED		P-VALUE
	MEAN	± STD	MEAN	± STD	
MXSK	2	± 1.8	2.5	± 2.6	0.438
BUI	1.1	± 1.8	1.4	± 1.6	0.607
TUI	0.1	± 1.1	0.5	± 1.4	0.243
TLI	0.1	± 1.0	0.2	± 1.2	0.858
BLI	2.3	± 2.3	2.3	± 2.3	0.942
MNSK	-3.5	± 3.6	-3.6	± 3.3	0.913
OB	0.1	± 1.4	0.7	± 2.1	0.2
GO	0.7	± 2.2	0.5	± 3.6	0.8
MPA	0.1	± 1.8	0.5	± 2.2	0.484

*significant p<0.05

Changes within the Control Groups by Sex

The Male Control Group from Time 1 to Time 2 demonstrated four variables with statistically significant changes (see Table 6 and Figure 5).

TABLE 6.– Comparison between T1 and T2 for the Male Control and Treated Groups

VARIABLE	CONTROL T1		CONTROL T2		P-VALUE	TREATED T1		TREATED T2		P-VALUE
	MEAN	±STD	MEAN	±STD		MEAN	±STD	MEAN	±STD	
MXSK	23.3	± 3.0	26.4	± 3.4	0.001*	24.5	± 3.2	27.9	± 4.3	0.000*
BUI	8.1	± 2.2	10.6	± 3.2	0.004*	7.9	± 3.0	9.9	± 2.3	0.001*
TUI	18.9	± 1.0	18.9	± 1.4	0.989	19.6	± 1.7	19.1	± 1.4	0.199
TLI	16.1	± 1.3	16.1	± 1.3	0.887	16.6	± 1.2	16.8	± 1.1	0.572
BLI	21.1	± 2.8	24.7	± 3.5	0.001*	21.7	± 2.9	25.5	± 2.6	0.000*
MNSK	60.1	± 4.7	66.2	± 6.7	0.001*	63.4	± 4.5	68.4	± 4.6	0.000*
OB	4.1	± 1.7	4	± 1.3	0.822	2.4	± 1.2	2.9	± 1.1	0.144
GO	131	± 4.1	130	± 6.2	0.336	134.3	± 5.3	134.6	± 7.2	0.744
MPA	37.6	± 3.2	37.4	± 4.5	0.794	35.7	± 6.1	35	± 7.8	0.329

*significant p<0.05

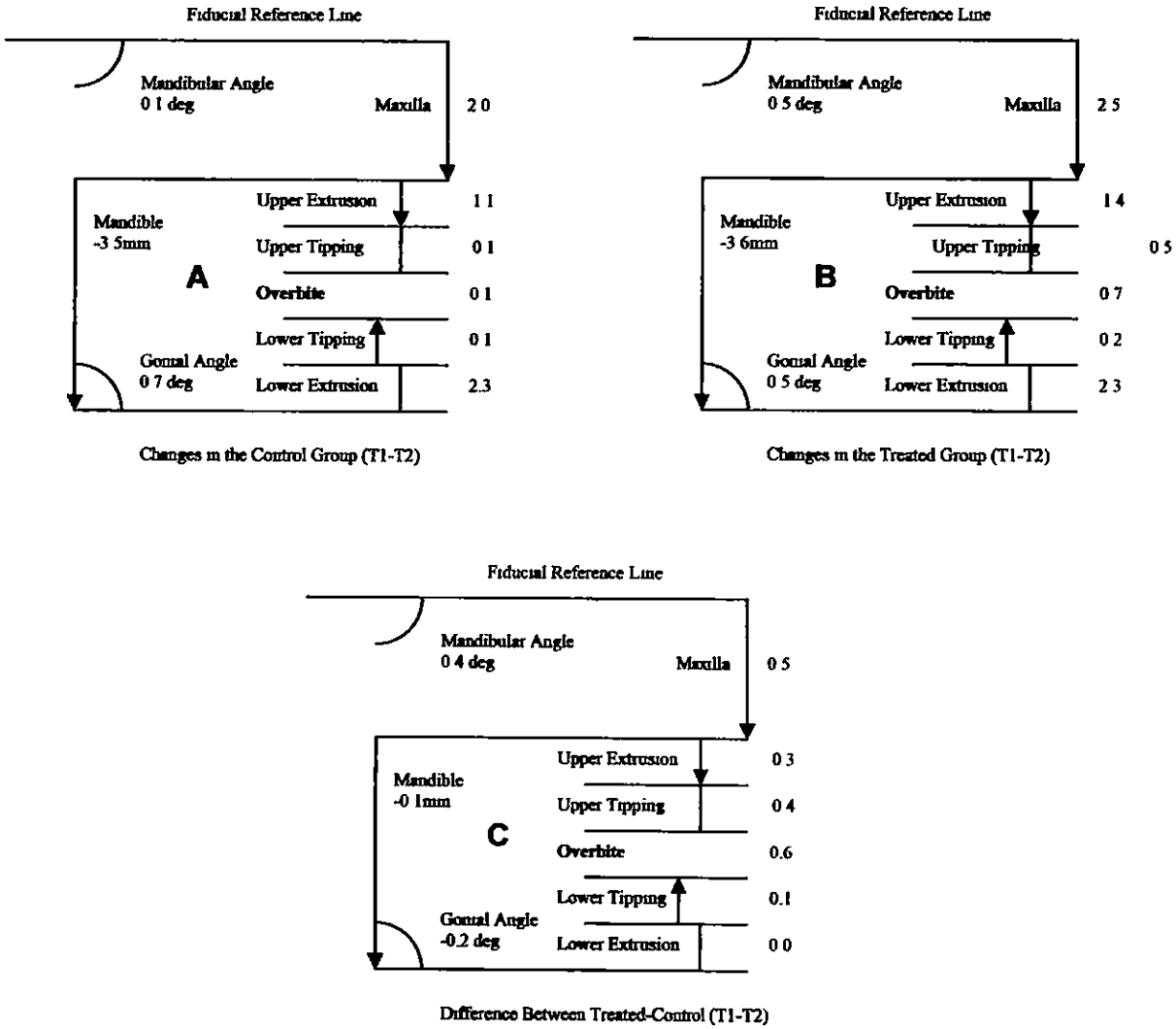


FIGURE 4. Changes in the Control group A Treated group B and difference between Control and Treated C.

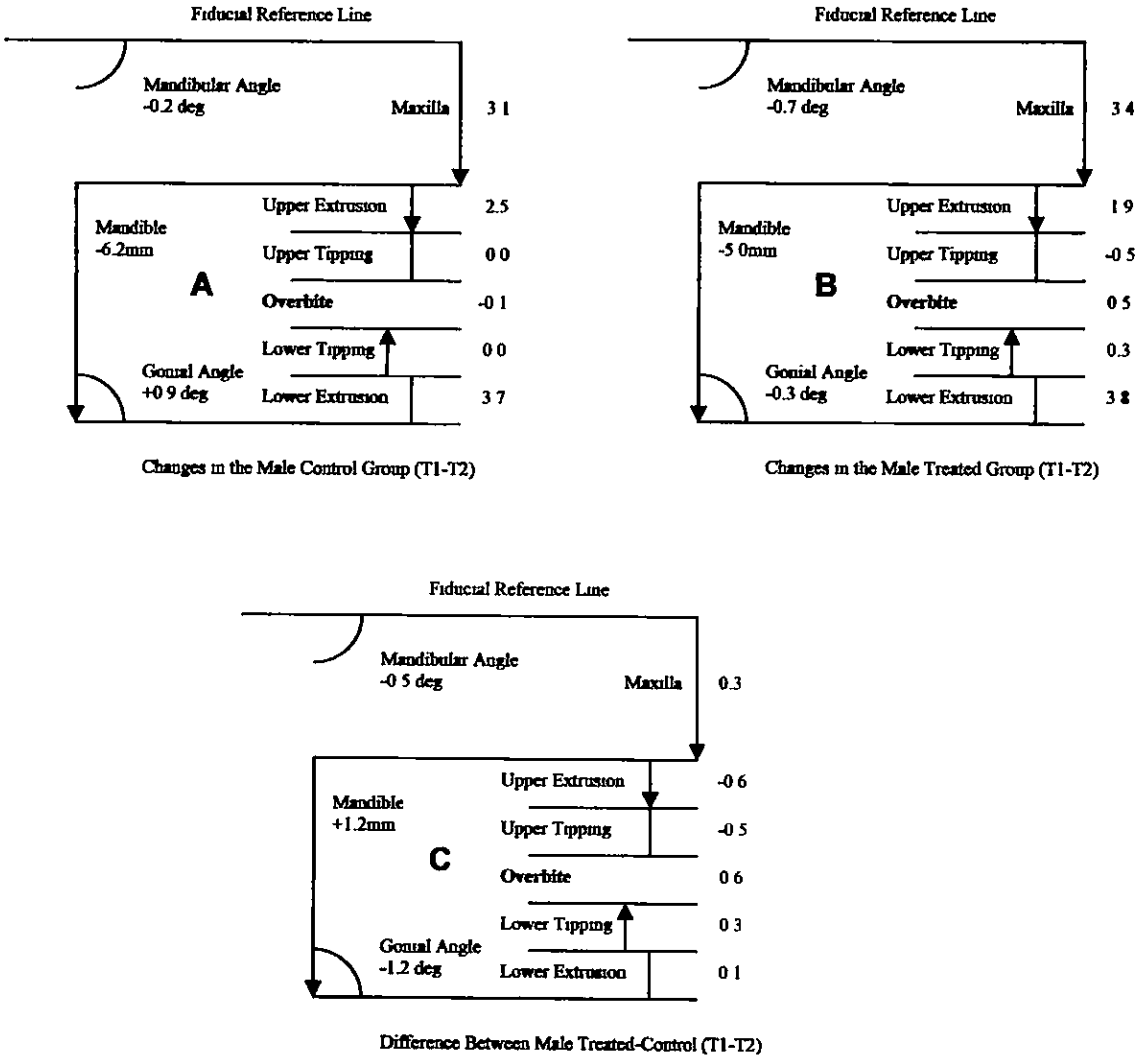


Figure 5. Changes in the Male Control group A. Male Treated B and difference between Male Treated and Control group C.

The maxillary skeletal height, upper incisor extrusion, lower incisor extrusion and mandibular skeletal height all increased significantly. All measurements in the Male Control Group except MNSK contributed a positive effect on bite closure. Overbite decreased by 0.1 mm.

The Female Control Group from Time 1 to Time 2 demonstrated three variables with statistically significant changes (see Table 7 and Figure 6). The maxillary (MXSK) and mandibular (MNSK) skeletal heights increased during the observation period by 1.3 mm and 1.8 mm respectively. The lower incisors of the female group extruded (BUI) by 1.4 mm from Time 1 to Time 2, also a significant increase. All variables for the Female Control Group except MNSK and TUI had a positive effect on Overbite decrease. MNSK had a negative impact on overbite decrease and TUI did not change in the Female Control Group from Time 1 to Time 2.

TABLE 7.– Comparison between Time 1 and Time 2 for the Female Control and Treated Groups

VARIABLE	CONTROL T1		CONTROL T2		P-VALUE	TREATED T1		TREATED T2		P-VALUE
	MEAN	±STD	MEAN	±STD		MEAN	±STD	MEAN	±STD	
MXSK	24.3	± 5.4	25.6	± 5.1	0.002*	24.4	± 3.7	26.2	± 5.0	0.008*
BUI	8.9	± 2.6	9.2	± 2.7	0.297	9.6	± 3.1	10.6	± 3.1	0.013
TUI	18.7	± 1.6	18.7	± 2.2	0.755	18.2	± 1.9	19.3	± 1.6	0.002*
TLI	15.4	± 1.8	15.6	± 1.8	0.475	16.3	± 1.6	16.4	± 1.5	0.706
BLI	20.9	± 2.9	22.3	± 3.0	0.007*	22.5	± 3.3	23.9	± 4.0	0.023
MNSK	60	± 4.9	61.8	± 4.3	0.002*	64.6	± 6.3	67.3	± 7.6	0.005*
OB	3.9	± 1.6	4.1	± 2.3	0.603	2.1	± 2.0	2.9	± 1.4	0.19
GO	127.7	± 3.8	127.1	± 3.4	0.318	131.8	± 5.9	130.8	± 5.9	0.313
MPA	33.8	± 3.3	33.7	± 3.4	0.787	37.8	± 9.1	37.2	± 7.9	0.456

*significant p<0.05

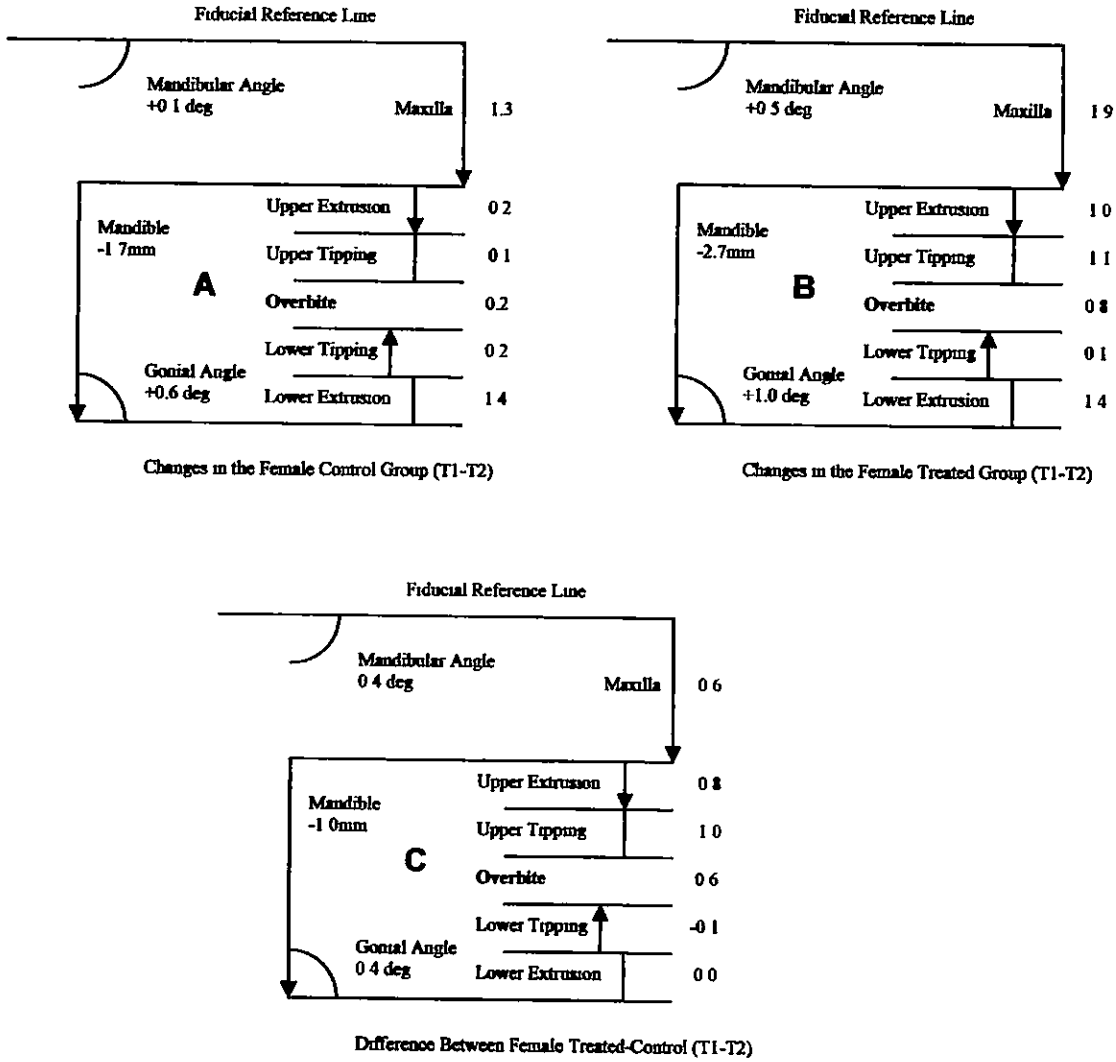


Figure 6. Changes in the Female Control group A. Female Treated group B and difference between Female Treated and Control

Changes Within the Treated Group by Sex

The Male Treated Group had four variables that changed significantly during the observation period (see Table 6 and Figure 5). From Time 1 to Time 2 the mandibular and maxillary skeletal heights increased significantly, by 5.0 mm and 3.4 mm respectively. The upper and lower incisor (BUI and BLI) measurements in this group both showed increases (i.e. extrusion)-of 2 mm and 3.8 mm respectively. In the Male Treated Group Go, MNSK and TUI contributed to a decrease in overbite. MXSK, BUI, TLI, BLI and MPA contributed to an increase in overbite. In the Treated Male Group, overbite did increase by 0.5 mm from Time 1 to Time 2.

In the Treated Female Group, at $p < 0.01$, three variables changed significantly during the observation period (see Table 7 and Figure 6). Mandibular and maxillary skeletal heights increased, by 2.7 mm and 1.8 mm respectively. The upper incisors (TUI) uprighted significantly, by 1.1 mm. Overbite increased by 0.8 mm in the Female Treated Group, with positive contributions by all variables except MNSK.

Changes in Treated versus Control Groups by Sex from Time 1 to Time 2

When comparing changes in the Male Treated versus Control Groups, no statistically significant differences were observed (see Table 8 and

TABLE 8. –Comparison of changes from Time 1 to Time 2 between the Male and Female Control and Treated Groups

	MALES					FEMALES				
	CONTROL		TREATED		P-VALUE	CONTROL		TREATED		P-VALUE
	MEAN	±STD	MEAN	±STD		MEAN	±STD	MEAN	±STD	
MXSK	3.1	± 2.0	3.4	± 2.2	0.733	1.3	± 1.3	1.9	± 2.7	0.441
BUI	2.5	± 2.1	1.9	± 1.5	0.47	0.2	± 0.9	1	± 1.5	0.097
TUI	0	± 1.2	-0.5	± 1.2	0.36	0.1	± 1.0	1.1	± 1.3	0.022
TLI	0	± 0.7	0.3	± 1.5	0.589	0.2	± 1.0	0.1	± 0.9	0.75
BLI	3.7	± 2.3	3.8	± 1.5	0.834	1.4	± 1.7	1.4	± 2.3	0.955
MNSK	-6.2	± 4.1	-5	± 2.4	0.409	-1.7	± 1.7	-2.7	± 3.5	0.339
OB	-0.1	± 1.4	0.5	± 1.2	0.259	0.2	± 1.4	0.8	± 2.6	0.393
GO	0.9	± 2.6	-0.3	± 3.0	0.361	0.6	± 2.1	1	± 4.0	0.725
MPA	0.2	± 2.3	0.7	± 2.3	0.641	0.1	± 1.4	0.5	± 2.8	0.617

*significant $p<0.05$

Figure 5). The overbite in the Treated Group increased slightly, by 0.5 mm while, overbite in the Control group decreased by 0.1 mm. GO moved in different directions in the Male Treated and Control Groups. GO in the Male Treated increased by 0.3mm and decreased by 0.9mm in the Male Control.

Comparison of the Female Treated versus Control Groups demonstrated one statistically significant change. TUI was significantly greater in the Female Treated than the Female Control. Overbite increased in both these groups with positive contributions from all variables except MNSK (see Table 8).

Measurement Error

Twenty-four lateral cephalographs were randomly selected to assess the amount of investigator error associated with measuring the six linear measurements using a digital caliper and the two angular measurements

using a protractor. The twenty-four radiographs were measured for a second time, and the two sets of means compared for each variable using intra-class correlation coefficients (see Table 9). All linear measurements were made to the nearest 0.1 mm and the angular measurements to the nearest 0.5°. The measurement error was very small, with all reliability coefficients between 97% and 99%.

Tracing Error

In addition to evaluating measurement error, the investigator tracing error was assessed by selecting twelve sets of pre-treatment and post-treatment lateral cephalograms and retracing them. The twenty-four radiographs were traced and measured for a second time, and the two sets of means compared for each variable using intra-class correlation coefficients (see Table 10).

TABLE 9. -- Describing Measurement Error

VARIABLE	MEASUREMENT 1		MEASUREMENT 2		R COEF
	MEAN	± STD	MEAN	± STD	
MXSK	24.4	± 3.8	24.3	± 3.8	0.999
BUI	9.6	± 2.1	9.6	± 2.1	0.997
TUI	18.3	± 1.6	18.2	± 1.6	0.996
TLI	15.8	± 1.8	15.9	± 1.9	0.971
BLI	21.2	± 3.8	21.2	± 3.8	0.999
MNSK	61.5	± 5.9	61.5	± 5.9	1.000
OB	3.3	± 2.3	3.4	± 2.4	0.978
GO	128.1	± 5.0	127.8	± 4.8	0.993
MPA	35.1	± 7.5	35.1	± 7.5	0.999

TABLE 10. – Describing Tracing Error

VARIABLE	TRACING 1		TRACING 2		R COEF
	MEAN	± STD	MEAN	± STD	
MXSK	1.9	± 2.0	1.8	± 2.0	0.994
BUI	0.7	± 1.4	0.9	± 1.5	0.964
TUI	0.1	± 1.7	0	± 1.4	0.817
TLI	0.6	± 0.7	0.6	± 0.9	0.883
BLI	1.1	± 1.7	1.2	± 1.9	0.924
MNSK	2.3	± 2.8	2.4	± 2.8	0.975
OB	0.2	± 1.3	0.3	± 1.4	0.809
GO	-1.3	± 2.0	-1.1	± 2.0	0.97
MPA	-0.6	± 1.5	-0.5	± 1.6	0.884

The reproducibility was excellent (≥ 0.75), as all intraclass correlation coefficients for the means of all variables were between 0.80 and 0.99.

DISCUSSION

The primary purpose of this investigation was to determine whether particular skeletal and dental components of the vertical dimension of occlusion were different in subjects who had orthodontic treatment in conjunction with extraction of all four permanent first molars as compared to orthodontically untreated controls. Overall, there was a slightly greater increase in mean bite depth in the thirty Treated cases as compared to the Control group from pre-treatment (T1) to post-treatment (T2). Except for a negative impact from the mandibular plane angle (SN-MP) on the increase in overbite, all of the other variables in both the Treated and Control groups contributed to an increase in overbite (see Table 5 and Figure 4). It must be noted that none of the mean changes in the variables studied in the Treated Group from pretreatment to post-treatment were statistically different from those measured in the Control Group during the same time interval.

Skeletal Changes

There were no statistically significant differences between the Control and the Treated groups when comparing the mean changes for the variables measuring skeletal change-i.e., MNSK, MXSK, Go and SN-MP (see Figure 4 and Table 5). It was noted that there was a significant difference at Time 1 between the Treated and Control Groups with respect to MNSK, OB and Go.

However, when looking at the changes from Time 1 to Time 2 that occurred in the Treated and Control Groups (see Table 3), there was a striking similarity in the variables that changed significantly between Time 1 and Time 2. The two variables measuring linear skeletal changes-MNSK and MXSK-showed significant increases in both the Treated and Control Groups from Time 1 to Time 2. So, even though MNSK was significantly different at Time 1 between Treated and Control, both group showed significant increases of a very similar amount -3.5 mm for Control and 3.6 mm for Treated (see Table 5). Also noteworthy was the similarity in the per year changes in the Control Groups in this study and three previous studies using the same vertical analysis (see Table 4). All four Control Groups showed increases in MXSK and MNSK (negative sign indicates that this variable had a negative contribution to open bite correction). The increases were very similar in Dietrich (1992), Bazzucchi (1996), Damon (1995) and the present study. All but Damon's study (deep bite correction) analyzed the effect of different treatments on patients with open bite. The starting Control groups were chosen to be similar to different Treated groups in these four studies. This suggests that regardless of how the Control Group might differ at Time 1 from the Treated Group, the changes that occur in these skeletal variables in untreated individuals over time are fairly uniform.

Dental Changes

The vertical analysis used in the present study enabled the investigator to separate bodily movements of the upper and lower incisors from tipping movements (see Figures 1, 2 and 3). There was virtually no difference in the amount of incisor bodily extrusion (BUI and BLI) between the Control and the Treated groups (see Table 5). The present study also showed no significant difference between the Control and Treated groups in the amount of tipping movements of the upper and lower incisors (see Figure 4). So, incisor angulation was under operator control and did not change in the absence of orthodintic treatment.

The Treated Group in this study underwent significant increases in BUI and BLI from T1 to T2. The Control Group underwent similar significant increases in BUI and BLI during the same time period (see Table 3). This is evidence that extraction of four first molars with subsequent orthodontic treatment to correct the existing malocclusion results in little difference in dental changes (extrusion/intrusion and tipping) from individuals whose changes result from growth and development.

The Control Groups compared in Table 4 showed very similar changes/year in mean tipping and bodily movements (TUI, TLI, BLI, BUI). Again that indicates that regardless how well matched treated and control groups are initially, untreated individuals undergo similar changes over time in the variables analyzed. It is then reasonable to conclude that by subtracting

the changes that occurred in the Control Group from the Treated group gives a reliable indication of the changes that can be attributed to treatment alone (see Figure 3).

Angular Changes

The normal cephalometric value for gonial angle is 123°± 5°, plus or minus five degrees (Bell, 1980). From the initial radiographs it was seen that the Treated group had a significantly greater mean gonial angle than the Control group at Time 1; Treated 132.9° and Control 129.3° (see Table 2). Both initial measures are increased over the norm. However, the initial difference between the two groups had no impact on the change that occurred in both groups from Time 1 to Time 2. Neither the Treated group nor the Control Group had a significant change in GO in the time interval studied. There was no statistical difference in the mean change from Time 1 to Time 2 between the Treated and Control groups. Both the Control and Treated Groups showed a slight closing of the gonial angle with time (see Figure 3 and Table 5).

The mean change/year in GO of the Control group in this study is the same as that observed by Bazzucchi (1996) and very similar to Dietrich (1992) and Damon (1995) (see Table 4). All observed a slight closing of the gonial angle as well. Again, this furnishes evidence that although the initial measurements for GO angle in the Treated and Control groups were significantly different, one can still expect the untreated group's changes over

time to not be affected by this initial difference. Therefore the difference between the change in the Treated value and the change in the Control value may be taken to represent treatment effect.

From the initial radiographs, there was no significant difference in the measurement for SN-Mandibular Plane between the Control (35.3) and the Treated Groups (36.9) (see Table 2). With a normal SN-MP of 32 degrees, these initial measurements represent an increased mandibular plane angle over the norm. There are several different definitions of what consititutes a "high angle" case in orthodontics. In their "Examination Information" booklet, The American Board of Orthodontists considers the minimum mandibular plane angle to be 28° in a "high angle" case. This can be translated into a SN-MP of 35° because on average, SN-MP is seven degrees greater than the FH-MP measurement (Proffit 2000).

With normal growth and development in an adolescent patient, one would expect the mandibular plane angle to increase about one degree every three to four years (McNamara 1986). Both the Control and Treated Groups in this study exhibited a decrease in SN-MP over the thirty-eight month observation period, 0.1° and 0.5° respectively. No significant difference was found between the mean changes of the Control and Treated groups (see Table 5 and Figure 4). Moreover, a significant change was found neither in the Control group nor in the Treated Group during the time interval studied (see Table 3).

The Control group exhibited the same change/year (0.1 mm) in SN-MP as did Bazzucchi's (1996). Damon (1995) and Dietrich (1992) had similar values (see Table 4).

Given the closeness in initial values of the Treated and Control groups in SN-MP, and the similarity in changes/year of the Control value in this study and in the past studies noted, one could reason that any difference over the time interval studied noted clinically in the Treated group from the Control group could be considered Treatment effect. That is to say, the extraction of four first molars with orthodontic treatment resulted in a 0.4 mm greater closure of the mandibular plane angle over untreated subjects (see Figure 4 and Table 5).

Overbite Changes

The initial overbite for the Treated Group was significantly less than for the Control Group (see Table 2). However, the mean increase in overbite seen in the 2 groups were not significant different from each other (see Table 5). Moreover, neither the Treated nor Control group had a significant increase in overbite from Time 1 to Time 2 (see Table 3). Also, the change/year in the Control group in this study was the same as Bazzuchhi (1996) and similar to the other studies' (see Table 4). The initial Control Group overbite was 1.5 mm more than Ricketts' ideal value of 2.5 mm whereas the initial Treated Group value was 0.3 mm less than the Ricketts' value. Given this data one can reasonably conclude that any difference between change in Treated

group from change in Control group was Treatment effect (see Figure 4 and Table 5). In this study, overbite increased 0.6 mm in Treated group over Control group.

It was noted that in the vertical analysis used in the present study, there was a tendency to slightly overestimate the amount of vertical incisor overlap (OB) as compared to a direct clinical measure. Clinically, one measures the severity of open bite relative to the occlusal plane. In the present investigation, all linear measurements were made relative to a constructed horizontal reference line (Pt point to Orbitale +3 mm) that approximates the Frankfort Horizontal plane. Normally, the horizontal plane and the occlusal planes will diverge anteriorly 11°, plus or minus 3° (Graber, 1985). As the anteroposterior distance between the upper and the lower incisors increases, so does the difference between the clinical measurement and the measurement used in the present study (see Figure 7).

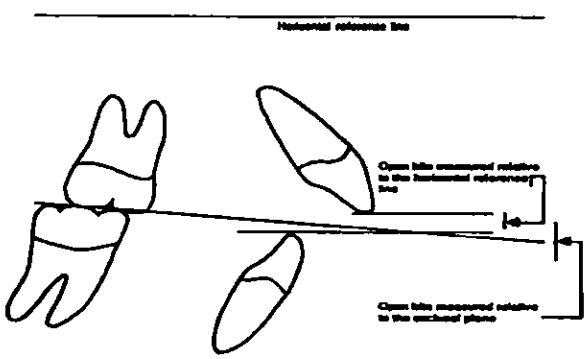


Figure 7. Methods of open bite measurement

Differences Between Treated and Control for Male and Female Groups

The average age of the sample at the start of treatment was about twelve and one-half years and ended at about age fifteen and one-half. With the end of active pubertal growth occurring at about fourteen years of age in females and two years later in males (Foley, 1992), one would expect more skeletal growth from the males in the study than the females. Both the male treated and control groups had about double the values for MNSK and MXSK during the thirty-eight month time interval over the female treated and control groups (see Table 8).

The Male Control and Treated groups both had significant increases from Time 1 and Time 2 in MXSK, MNSK, BUI and TUI (see Table 6 and Figure 5). These directly parallel the changes seen in the overall Control and Treated Groups (see Table 3). In comparing the ten male control subjects with the twelve male treated subjects, no statistically significant differences were observed when comparing changes from Time 1 to Time 2 (see Table 8).

Clinically, it is interesting to note that the Treated Male Group experienced a 20% less (5 mm vs 6.2 mm) increase in MNSK than the Male Control Group. This could be seen as a treatment effect. As first molars are extracted and second molars are protracted during treatment, there would be a closing of the posterior wedge, less clockwise rotation of the mandible that can result from extrusion of molars and subsequent less increase in

mandibular skeletal height. There is a notable association between this relative decrease in MNSK in treated males and the much greater growth seen in males over females in this time period. Whether the treatment effect is perhaps due to less extrusion of the molars in the treated males versus treated females warrants further study. Treated females experienced a relative increase of MNSK over Control females in the present study (see Table 7 and Figure 6).

The only group studied whose mean change resulted in a flaring of incisors (TLI or TUI) was the male treated group (see Table 6 and Figure 5). This 0.5 mm. proclination is directly under the control of the clinician. The mean starting overbite of the male treated group of 2.4 mm is almost identical to Rickett's value of 2.5 mm. The probable result in treated males of relatively less increase in MNSK was a greater deepening of the bite than desired. The clinician can easily lessen this effect by a slight flaring of the upper incisors. The T2 mean overbite for treated males was 2.9 mm and may have even been higher during the course of treatment.

The changes in the linear variables studied were consistently less in the Female Treated and Control Groups as compared to the Male groups. (see Table 8). Less growth for females during the observation period is a reasonable explanation. Although statistically significant increases were noted in MXSK, BLI, MNSK in the Female Control group and in MXSK, BUI, BLI, and MNSK in the Female Treated group (see Figure 6 and Table 7), these

changes were considerably less than in the Male groups. BUI in the Female Control Group barely changed from Time 1 to Time 2.

TUI in the Female Treated Group was significantly increased from Time 1 to Time 2 in contrast to the decrease seen in Male Treated (see Table 8). It is striking that MNSK, a linear skeletal measure, contributes to an increase in overbite in the Male Treated but to a decrease in overbite in the Female Treated, whereas TUI does the opposite-decrease in Male Treated overbite and increase in Female Treated Overbite. TUI is totally under clinician control while MNSK is affected by both growth and treatment. So the Female Treated group, which started with a mean overbite of only 2.1 mm. (ompared to 2.4 mm for Male Treated) and ended with a mean overbite of 2.9 mm.(same as Male Treated), apparently needed clinician intervention through uprighting of the upper incisors to achieve the desired overbite (see Figures 4 and 5 and Tables 6 and 7).

Comparison to Previous Studies

Only Aras (2002) has published a scientific study examining the effect of first molar extractions and orthodontic treatment on the vertical dimension of occlusion. His first molar extraction subsample consisted of eight subjects as part of a larger study involving orthodontic treatment with extraction of first and second premolars as well. All of his patients had varying degrees of anterior open bite along with increased mandibular plane angles (pre treatment mean SN-GoGN 42.81°). He observed a significant decrease in the

mandibular plane angle-a closing rotation of the mandible from pre to post treatment. He did not have an untreated control group, however, with which to compare effects due to growth. He did select subjects with an average pre-treatment age of fifteen years so that growth would not have been as important a component in the changes in his study as they are in the present study, with an average pre-treatment age of 12.5 years. Another difference from the present study is that all of his subjects had an anterior open bite. The present study subjects had a mean initial overbite of 2.2 mm. Using Ricketts' (1982) ideal value of overbite of 2.5 mm suggests that the present study's subjects have a slightly reduced overbite than seen in the ideal.

Scientific investigations have also been carried out in patients where the first and second molars protracted forward substantially following first premolar extraction. These studies revealed that there was no decrease in the mandibular plane angle (Staggers 1990; Cusimano et al. 1993). In these studies, the extrusion of molars due to growth and treatment was stressed as a factor preventing the closing rotation of the mandible. Staggers (1990) attributed the extrusion to the generally extrusive nature of all orthodontic mechanics in her study. Some investigators have emphasized the necessity of trying to prevent extrusion during protraction of the molar teeth, and a vertical chin cup has been advocated in full-bonded appliance therapy. (Schudy 1964; Pearson 1978). Cusimano et al. (1993) analyzed high angle patients with an average age of 11 years 10 months. According to these

authors significant extrusion of molar teeth involved compensatory vertical eruption of the molar teeth into the intermaxillary space to keep pace with the increase in anterior facial height. The present study also analyzed moderately high angle patients (mean SN-MP 36.9°) and also showed no significant decrease in mandibular plane angle that could attributed to treatment effect. Asessing the mean SN-MP as moderately high is based on the norm provided by Proffit as 32°. (Proffit 2000). Although neither the vertical or horizontal position of the second molars were assessed in the present study, it is reasonable to infer that any potential decrease in the vertical dimension due to first molar extractions alone were offset by extrusive mechanics on the second molars as the prime anchorage units for the orthodontic corrections in the arches anterior to the first molar extraction spaces. No practitioners who provided the cephalograms analyzed in this study reported the use of extraoral force or intraoral additional anchorage (i.e., TPA or Nance) in their treatment mechanics.

The present study agrees with the study by Elham et al. (2000) in which both lower first molars were extracted due to caries and no other treatment was performed. On average, they found no significant change in the vertical relations of the jaws save that caused by normal growth and development. On average there was no change in the angulation of the incisors to the bases. The difference in approach in the present study was that all four first molars were extracted and orthodontic treatment was done.

However, any change observed in the Treated group in the present study could be attributed to growth based on the lack of statistically significant differences from the Control Group.

Arvystas (1977) concluded from his case study of a sixteen-year old adolescent girl that four first molar extractions with mesial movement of the second molars during treatment aided in closure of open bite, with counterclockwise rotation of the mandible. This was not seen in the present study. However, Arvystas' patient had an open bite extending to the second premolars on one side and first molars on the other-an extreme case. The subjects in this study did not present with the extent of hyperdivergence or anterior open bite seen in Arvystas' study. Also, the subjects in this study had growth potential with an average age of 12½ years.

Garlington and Logan (1990) observed a significant decrease in lower anterior face height when maxillary first premolars and mandibular second premolars were extracted. However, total anterior face height was not reduced, which corresponds to the measurement MNSK in the present study. Garlington and Logan noted mesial drift of mandibular molars. The present study employed mechanotherapy on those teeth, which tends to cause extrusion and accompanying alveolar growth.

Limitations

The original Control Group of thirty subjects was revised to twenty-five subjects in the course of gathering data for this study. Therefore, a matched

design was not possible. There were differences noted in some initial measurements between Treated and Control groups that make direct comparison between the changes in these groups during the observation period more difficult.

Although no significant differences were noted between Treated and Control groups in any of the measurements used in this study, it should not be concluded that treatment caused no change. The statistical tests performed were only designed to detect to a 95% certainty (alpha error set at 0.05) that there were differences in the variables studied between treated and untreated groups. No such difference was detected. But it was not proven that there was no difference. A much larger treated sample would have been necessary to detect this Type II(B) error. It would have been necessary to set B error at 0.1 in order to be 90% sure that there was no difference between the treated and untreated groups.

For the Treated Group, the radiographs were taken on the cephalometers of the clinicians providing the radiographs. Although the possibility of magnification variability exists with regard to the linear measurements in this investigation, the assumption was made that both T1 and T2 cephalograms were made using the same cephalometer. So, magnification was assumed to be consistent for all pairs of cephalograms.

SUMMARY AND CONCLUSIONS

The primary purpose of this investigation was to determine whether or not particular skeletal and dental components of the vertical dimension of occlusion were different in patients who had orthodontic treatment in conjunction with extraction of all four permanent first molars as compared to orthodontically untreated controls. Additionally, an analysis of the changes in the vertical dimension of occlusion was done between pre-treatment and post-treatment for the treated patients and for the same time interval for the untreated controls. Changes that occur in these variables for subjects who had orthodontic treatment with first molar extractions versus untreated controls were also analyzed separately for males and females.

Thirty patient records were provided by ten orthodontists using the criteria that all four permanent first molars were extracted subsequent to the Time 1 cephalometric radiograph and prior to orthodontic treatment. A Control Sample of untreated individuals with similar mean age and time interval of observation was chosen from the Bolton Collection, Cleveland, Ohio.

A cephalometric analysis was utilized which contains six linear and two angular measurements (Kishiyama 1987) to evaluate dental and skeletal changes from time one to time two for both the Treated Group and the

Control Group. The analysis isolated tipping movements from bodily movements of the upper and the lower incisors and assessed vertical skeletal changes in the maxilla and the mandible.

Analysis of the data revealed that:

1. No statistically significant changes in any variables were found between Time 1 and Time 2 in comparing Treated and Control Groups.

2. Overbite did increase slightly in both the Treated and Control groups

3. The changes in the variables measured in the Treated Group appear to be largely due to growth changes during the time interval studied.

4. First molar extraction may result in decreased mandibular skeletal height in the male treated group relative to male controls. This effect was not seen in the female treated versus female control group and may be intertwined with the greater growth experienced by males or the smaller muscle mass in females.

5. The "wedge hypothesis" is supported for males but not for females.

6. Extraction of permanent first molars prevented an increase in the vertical dimension.

7. In males, extraction of first permanent molars may decrease mandibular skeletal height.

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