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ACTIVE VERTICAL CORRECTOR IN NON-EXTRACTION TREATMENT OF ANTERIOR OPEN BITE MALOCCLUSION

by

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ACTIVE VERTICAL CORRECTOR IN NON-EXTRACTION TREATMENT OF ANTERIOR OPEN BITE MALOCCLUSION

Abstract

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The purpose of this investigation was to evaluate the relative contributions of two skeletal and four dental components to open bite correction in two phase non-extraction treatment for open bite malocclusion. Twenty-nine subjects were selected by one orthodontist from his private practice in Fort Wayne, Indiana. All subjects lacked vertical incisor contact at the start of treatment and had adequate initial, end of phase 1, and deband lateral cephalograms. Each subject in the treated group was matched by age, sex, and treatment time with an untreated subject from the Broadbent Bolton Collection, Cleveland, Ohio.

A cephalometric analysis, which utilized six linear and two angular measurements, was used to evaluate dental and skeletal changes during phase 1 (T1-T2), phase 2 (T2-T3) and over the total treatment period (T1-T3). The analysis isolated tipping and bodily tooth movements of the

upper and the lower incisors and assessed vertical skeletal changes in the anterior region of the maxilla and mandible. Analysis of the data revealed no statistically significant ($p < 0.002$) changes in any variables during phase 1 (T1-T2) or phase 2 (T2-T3) treatment intervals. Overbite was significantly improved ($p \leq 0.002$) during the T1-T3 time interval. Hence, we conclude that two phase treatment with the active vertical corrector followed by fixed orthodontic appliance treatment results in a statistically significant increase in incisor overbite. The observed change was the result of small, but clinically significant, changes in relative mandibular vertical growth bodily incisor extrusion, and lingual tipping of the lower incisors.

DEDICATION

To my brothers, and my parents. Thank you for all the love and support.

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INTRODUCTION

One of the most challenging treatment for an orthodontist are patients that present an open bite. Common features of the open bite patients are an increased lower facial height, steep mandibular plane angle, cant of the palatal plane, large interlabial gap, weak masticatory muscles. In such patients treatment with conventional orthodontics appliances may lead to a Class I occlusion. However, this often does not provide a satisfactory results in term of stability and facial esthetics. At present time the only definitive method of improving dentofacial harmony in this patients is by means of surgical superior repositioning of the maxilla. This procedure increases the interocclusal space and allows upward and forward autorotation of the mandible, thereby decreasing lower facial height and facial convexity. Dellinger reported on the use of a magnetic appliance to treat patients with skeletal open bite. This appliance resulted in intrusion of posterior teeth and an upward and forward autorotation of the mandible.

The purpose of this investigation was to evaluate the relative contributions of two skeletal and four dental components to open bite correction in two phase non-extraction treatment for open bite malocclusion. Twenty-nine subjects were selected by one orthodontist from his private

practice in Fort Wayne, Indiana. All subjects lacked vertical incisor contact at the start of treatment and had adequate initial, end of phase 1, and deband lateral cephalograms. Each subject in the treated group was matched by age, sex, and treatment time with an untreated subject from the Broadbent Bolton Collection, Cleveland, Ohio.

A cephalometric analysis, which utilized six linear and two angular measurements, was used to evaluate dental and skeletal changes during phase 1 (T1-T2), phase 2 (T2-T3) and over the total treatment period (T1-T3). The analysis isolated tipping and bodily tooth movements of the upper and the lower incisors and assessed vertical skeletal changes in the anterior region of the maxilla and mandible.

LITERATURE REVIEW

Vertical dimension is one of the most difficult parameters to control during orthodontic treatment. In particular, correction of anterior open bite is a challenging problem that presents the clinician with alternative treatment strategies. However, although many treatment modalities have been developed to correct discrepancies in the vertical dimension few case control and no random trials have been conducted required to compare the treatment response of these techniques.

Vertical control is important because patients with anterior open bites tend to be very self-conscious and concerned about their appearance. DeSmith and Dermant (1984) focused on public preferences for soft tissue profiles. They constructed nine different types of profiles composed of skeletal Class I, II, and III, each with a short, normal, and long lower facial height (LFH). Skeletal Class I with normal lower facial height was the most appreciated and skeletal Class I with short LFH was highly appreciated. Importantly, long LFH was judged less attractive in all skeletal groups.

Bjork (1969) examined methods for predicting mandibular growth rotation in a longitudinal cephalometric study of one hundred subjects with metallic implants in the mandible and maxilla. He described two types of

extreme growth patterns. One pattern results in a deep overbite and the other an open bite. Bjork termed these patterns forward or backward rotations of the mandible. He listed seven structural signs which could be used for prediction of backward rotation associated with a skeletal open bite:

1. A backward inclination of the condylar head.
2. A straight or backward curving mandibular canal.
3. A concave or notched lower border.
4. A less prominent chin button.
5. Decreased interincisal angle.
6. Mesial inclination of molars and premolars.
7. Increased lower mandibular facial height.

Bjork noted that all of these signs were not present in all patients, but the greater the number present, the more predictable was backward rotation of mandibular growth. He excluded mandibular plane angle from his list of predictors. From his implant study Bjork (1963) noted that the lower border of the mandible underwent radical restructuring during growth and development which made it a poor predictor or tool for measuring vertical development.

In addition to these predicting factors Skieller et al., (1984) found through another implant study three more variables which, in combination, gave a good estimate (86%) of future mandibular growth rotation. Those variables were:

1. Mandibular inclination, represented by three alternatives.

   a. Proportion between posterior facial height (PFH) to anterior facial height (AFH).

   b. Lower gonial angle represented by nasion-gonion-menton(N-Go-Me).

   c. Inclination of lower mandibular border to sella-nasion (MD-S-N).

2. Shape of the lower border of the mandible (angle formed between Me-Go and tangent to the lower border of the mandible). Such an angle is increased in a horizontal grower.

3. Inclination of the symphysis (angle formed between a tangent anterior to the border of the symphysis and perpendicular to S-N through S).

This group concluded that 86% of the variation can be explained these morphologic factors. However, it is critical to point out that none of these predictor showed has been verified wit an independent sample.

Moss (1964) reviewed the literature that had attempted to standardize facial growth through cross-sectional or longitudinal studies. He noted that no matter what type of study, all the authors reached the conclusion that there was a great range of individual variation. He believed the "standards" obtained from these studies could only be used as indicators of the general trend of growth direction. Importantly this data enabled the clinician to satisfactorily diagnose or predict facial growth. He described individual variation as the rule and not the exception. Moss theory is based on the idea that form, as well as size and shape, of a bone, its spatial position, and

its growth are direct and mechanically obligatory responses to the growth of its functional matrix. The functional matrix is defined as "the tissues and spaces related to a given function". Based on this, Moss indicated that vertical facial growth reflects changes in the functional areas of vision, respiration, olfaction, digestion, and speech. The bones protecting or supporting the soft tissue and spaces concerned with these functions include the maxilla and mandible. The biologic processes that Moss suggested be studied are not those of bone growth *per se* which are secondary, but rather those of the functional matrix, which are primary. "*To this extent, orthodontic therapy, is and should be an art rather than a science.*" (Moss, 1964)

According to Schudy (1963, 1964) the terms retrognathic and prognathic were not indicative of vertical direction but were measures of antero-posterior variation. Schudy introduced the term hypodivergent indicating a decreased vertical dimension and hyperdivergent indicating an increased vertical dimension. He described the direction of facial growth as a dynamic and harmonious growth that is due to an equilibrium between vertical and horizontal factors. Vertical factors are expressed by vertical growth and include:

1. Body and frontal process of the maxilla.
2. Dentoalveolar maxillary process.
3. Dentoalveolar mandibular process.

4. Body of the mandible.

In contrast anteroposterior growth is expressed by the following:

1. Mandibular.
2. Anterior aspect of the symphysis.
3. Posterior aspect of the tuberosity of the maxilla
4. Anterior aspect of the pterygoid process.
5. Nasal septum.
6. Retromaxillary suture system.

He also studied the ratio between lower PFH to AFH. He found this proportion to be a helpful tool in diagnosing extreme facial types. He established 76% to be representative of average facial type. In addition, Schudy found the occlusal mandibular angle (average of 16°) to also be a helpful diagnostic measure.

Forsberg et al., (1991) showed that the face height continued to increase into the fourth decade of life. They designed a twenty year longitudinal cephalometric study that focused on facial height and tooth eruption. The sample consisted of thirty patients, with a minimum age of twenty five years when they took the initial lateral cephalometric radiograph and with a mean age of forty five years old when they took the second film. The authors measured the changes in the vertical dimension and found that there was an average increase in the lower AFH of 1.6 mm due to tooth eruption with a clockwise rotation of the mandible. The dependent

relationship between vertical facial height and horizontal projection of the mandible has been recognized for some time.

McNamara (1981a) studied the frequency of occurrence of key components of Angle Class II malocclusion in 277 subjects with Class II malocclusion. The age of the sample ranged from eight to thirteen years. Only a small percentage of cases exhibited maxillary skeletal protrusion. On average the maxilla was found in a neutral position. The lower incisors were usually well positioned. The most common finding was mandibular skeletal retrusion. Half of the sample exhibited excessive vertical development. Due to his findings, McNamara suggested that treatment of skeletal Class II malocclusion should focus on controlling counterclockwise rotation of the mandible and stimulating mandibular horizontal growth rather than trying to restrict maxillary development.

Lundstrom and Woodside (1983) performed a longitudinal study of seventy cases aimed at determining whether the differences between the vertical and horizontal types of mandibular growth can be detected at an early age and whether the differences became more marked with age. They found that at an early age it was possible to see a prognathic mandible in the horizontal grower and a retrognathic mandible in the vertical grower. The horizontal cases showed, from age nine to fourteen years, a larger increase in the sella-nasion-prognathion angle (4-5°) compared with vertical cases (1°). In the horizontal cases the mandibular plane angle was also

decreased 4-5° . No significant difference was noted in the vertical grower in the same amount of time. This data was also supported by Cangialosi (1984).

Confirming that it is possible to detect a vertical or horizontal grower at an early age, even before the eruption of the first permanent molars, Nanda (1988) found that deep bite and open bite subjects grow differently. The deep bite samples were characterized by an increased upper AFH and a decreased lower AFH. The opposite was true for the open bite patients. He also found that PFH and ramal height did not differ significantly between the two samples. He also found a difference in the timing of the adolescent growth spurt associated the facial growth. Female open bite subject had a spurt at, twelve years, female deep bite at thirteen years, male open bite at fourteen years, and male deep bite fifteen years.

Lundstrom and Woodside (1981) radiographically compared a sample of vertical growers to a sample of horizontal growers. In the vertical grower, compared to the horizontal grower, the total AFH and lower AFH was higher, chin was more retrognathic, and the mandibular plane angle was steeper. There was no difference in the gonial angle between the two groups.

Wylie (1946) with a radiographic study showed that the amount of growth of the mandible was not different between patients with deep bite compared to patient with open bites. However, there was a difference in the

amount of posterior dental height between the two groups, with an increase in the open bite and a decrease in the deep bite compared to the average posterior dental height.

In a study of facial morphology in subjects with low angle, average angle, and high angle, 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 lower angle (17.1 mm), indicating that posterior dental eruption was generally greater in high angle cases. The percentage total AFH/ lower AFH was also found to be significantly greater in the high angle group (56.17%) than in the low angle group (51.85%). The width of the palate in the molar area was greater for low angle subjects (40.5 mm) compared to high angle subjects (35.6 mm).

Nahoun (1975) described two different types of anterior open bite; 1) patients with dentoalveolar open bite without any craniofacial anomalies due to habits such as tongue thrusting that prevented eruption of the teeth and 2) patients with anterior open bite with craniofacial dysplasia. The second group had many characteristics described by others; steep mandibular plane angle, obtuse gonial angle, increased lower AFH, and posterior inclination of the palatal plane. (Fields et al., 1984; Ellis and McNamara, 1984; Cangialosi, 1984; Sassuoni and Nanda, 1964; Opdebeeck et al., 1978).

Dung and Smith (1988) tested the validity of specific cephalometric values used to diagnose a patient with vertical growth direction. They used six groups consisting of thirty patients. The first group had the mandibular plane angle greater that 40°, with this as the only inclusion criteria. The second group had an occlusal mandibular plane angle greater that 22°. The third group had a palatal plane angle greater than 32°. The fourth group was based on the presence of a dental anterior open bite. The fifth group had the PFH:AFH ratio greater that 58% and the last group had the UFH:LFH ratio greater than 70%. None of these values *per se* showed any significant correlation with subsequent vertical growth.

Function and Facial Growth

Finger sucking is considered an etiological factor for open bite malocclusion. Larsson (1987) reviewed the literature on malocclusion reported to be caused by prolonged finger sucking. The author reported that the habit of finger sucking caused a reduction in alveolar growth. Most of the time, if the patient stops the habit before the pubertal growth spurt and if the lip function is normal, the open bite corrects by itself as a result of lip pressure. If the habit is continued after the pubertal growth spurt the open bite will be less likely to correct by itself. Another common finding was lengthening of the maxillary dental arch, and protrusion and proclination of the anterior teeth. The lower incisors were retroclined, but when the habit was prolonged they become proclined. Constriction of the maxillary arch

was also a common finding.

Severe nasopharyngeal obstruction is also believed to be one of the etiological factors causing an increase in vertical facial growth. The classic clinical example of the relationship between airway obstruction and aberrant craniofacial growth are the patients described with an "adenoid facies" by Ricketts (1968). These patients usually present with a mouth open posture, small nose with button-like tip, nostrils that are small and poorly developed, a short upper lip, prominent upper incisors, pouting lower lip, and " vacant " facial expression. Mouth breathing individuals have been Classically described as possessing a narrow, v-shaped maxillary arch, high palatal vault, proclined upper incisors, and a Class II dental relationship.

In contrast to Rickett's findings, Howard (1932), Leech (1958), and Huber and Reynolds (1946) found that 60% of mouth breathers had a Class I molar relationship, 30% had Class II, and 10% had a Class III. McNamara (1981a) supported Rickett's findings and found that on average his study sample with airway obstruction was also characterized by excessive anterior facial height and a steep mandibular plane.

Linder-Aroson and Backstrom (1960) compared facial type and occlusion in nose breathers and habitual mouth breathers. They noted that children with a long narrow face and a high narrow palate tended to have greater nasal resistance to air flow than those with a low broad palate.

McNamara (1981b) presented four cases of airway obstruction. The

first case was nonsurgical. The patient presented with a long and narrow face, narrow nose, and small nostrils - the Classic adenoid face. His lower facial height was 67 mm, the facial axis angle was -10° and the mandibular plane angle was 35°. After 3 1/2 years the patient had an increase in LFH of two mm, the facial axis angle opened one degree, and the mandibular plane increased one degree. The second case initially presented with the same characteristics and underwent adenoidectomy. One year postoperatively the patient had switched from a mouth breathing condition to nasal respiration. The patient showed a spontaneous closure of his open bite and a normalization of the transverse dimension between the maxilla and the mandible. The LFH changed from 69 mm to 68 mm, the mandibular plane angle decreased from 31° to 27°, and the facial angle decreased from -6° to -4°. The third case received both tonsillectomy and adenoidectomy. A follow-up examination 2 1/2 years postoperatively revealed, as in the second case, a decrease of 2 mm in LFH, instead of increasing at the rate 1 mm per year. The mandibular plane angle decreased from 40 to 34°. The fourth case had a submucous cleft of the soft palate. The surgeon performed a pharyngeal flap procedure because of velopharyngeal insufficiency. In contrast to the previous cases, this patient originally had a restricted airway which was completely closed by the surgical intervention, forcing him to become a mouth breather. His lower facial height increased from 68 mm to 70 mm, the mandibular plane angle changed form 26° to 32°, and the facial

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axis growth opened from -3° to -9°. These four case reports were presented to illustrate potential interactions between respiratory function and craniofacial growth pattern.

Vargervik et al., (1984) studied skeletal and neuromuscular changes on rhesus monkeys after two years of complete nasal obstruction with a nasal plug. EMG recording showed rhythmic discharge of the following muscles during the obstruction: geniohyoid, digastric, genioglossus, dorsal tongue fibers, and the lip elevator region. After removal of the nasal plug these EMG records disappeared. The skeletal changes that occurred during the two years were downward tipping of the palatal plane, an opening of the mandibular plane and the occlusal plane, and increases in both of upper and lower AFH. There was a tendency toward anterior crossbite and open bite. After removing the nasal plug and so reestablishing nasal respiration, there was a tendency for spontaneous improvement in the malocclusion.

Lowe et al., (1995) focused on the interaction between craniofacial structures, assessed by lateral cephalometry, and the tongue, soft palate, and upper airway size, determined from computed tomography scans. He examined twenty five control subjects and eighty patients with obstructive sleep apnea syndrome. A high apnea index was associated with a large tongue and greater soft palate volumes, an anteroposterior discrepancy between the maxilla and the mandible (Class II skeletal), open bite tendency, steep mandibular plane, increased LFH, increased maxillary and

mandibular molar height, and great obesity.

Muscle and Facial Growth

The interaction of soft tissue with the craniofacial skeleton has been focused on two aspects: 1) the effect that muscle has on bone modelling and, 2) the effect of muscle on the growth pattern of the cranioskeleton. The relationship between muscle function and cranioskeletal growth has been well studied.

Kreiborg et al., (1978) reported craniofacial growth in a case of congenital musculature dystrophy. A medical examination of the patient at three years of age revealed generalized muscular weakness, extensive palsies, and scoliosis of the cervical and thoracic vertebrae. Electromyographic recordings at the age of six demonstrated almost no activity in the temporal and masseter muscles. The lateral radiograph of the patient at age four showed an extreme anterior facial height caused by a pronounced backward inclination of the mandible. A clinical examination revealed a marked anterior open bite with occlusion limited to the second deciduous molars. The palate was high arched and narrow. Follow-up was maintained until age twelve. The patient from age four to twelve exhibited marked vertical development of the face with extreme backward rotation of the mandible and a downward-backward growth of the maxilla. Similar findings were observed by Proffit et al., (1968) in a nineteen year old female with muscular dystrophy.

Bakke and Michler (1991) described the correlation between the activity of the temporalis and masseter muscle and patients with anterior open bites and craniomandibular disorders. The first group of patients had anterior open bites. The second had anterior open bite associated with craniomandibular disorders such as TMD or muscular affections. The third group was a control group with no anterior open bite or craniomandibular disorders. The patients in the first group with open bite had a weaker maximal bite force compared to the control but stronger compared to the patient with open bite associated to craniomandibular disorders. Cephalometric data revealed a negative correlation between maximal bite force and vertical facial height. The patient with open bite and craniofacial disorders had higher values for facial height, mandibular plane angle, vertical jaw relation, and gonial angle compared to the other two groups.

Gardner et al., (1980), Phillips et al., (1982), and Behrents and Johnston (1984) reported alterations in the facial skeleton of growing experimental animals following unilateral obstruction of the motor nucleus of the trigeminal nerve. They were able to electrolytically produce a specific lesion of the trigeminal nerve. Other factors, such as sensory loss and tissue scarring, did not contribute to the cause of asymmetry as was criticized in previous studies involving reduction of nerve or muscles. Gardner et al. (1980) and Phillips et al. (1982) utilized non-operated animals and the contralateral side to the muscle paralysis as controls. The operated animals

showed marked asymmetries, loss in weight, and deviation of the mandible and the maxilla to the non-operated side. The muscles of mastication of the operated side appeared severely atrophic and the contralateral muscles did not show any hypertrophy compared to the non-operated animals. The operated side of the mandible was significantly shorter in total length, angular process length, and ramal width than the contralateral side. The condylar process and the glenoid fossa in the operated side showed marked resorption. The coronoid process also showed a reduction in length, height, and thickness on the operated side compared to the contralateral and to the non-operated animals. An anterior open bite was present asymmetrically on the innervated side and was accompanied by supra-eruption of the dentition.

Spronsen et al., (1992) compared the jaw muscle cross-sections of long face adults to normal adults. The comparison was made between the mid-belly cross sectional areas of the jaw muscles of thirteen long face and thirty five normal adults by means of serial MRI scans. In the long face group, the cross-sectional areas of the masseter, medial pterygoid, and anterior temporalis were respectively 30%, 22%, and 15% smaller than in the control group. This difference was explained in part by the lower values of maximum molar bite force in the long face patient compared to normal population. The belief that the adult patient with a long face syndrome has a weaker maximum molar bite force is supported by Proffit et al., (1983).

Profitt and Fields (1983) studied occlusal forces in children aged from six to eleven years during swallowing, simulated chewing, and hard biting. Forces in the normal and long face children were similar to those in long face adults. Individuals with long face patterns failed to gain strength normally in the mandibular elevator muscles.

Ingervall et al., (1989) found no correlation between mouth breathing and bite force in eighty one children from seven to sixteen years of age. The mechanical advantage of a lever system was an explanation for the differences in bite force. Throckmorton et al., (1980) demonstrated that there was a greater mechanical advantage for the elevator muscles of the mandible if the ramus of the mandible was upright and gonial angle was relatively acute. As the gonial angle increases, the mechanical advantage of the muscles decrease. This in part explains the difference in bite force between the long face subjects compared to normal subjects.

The effect of hyperactivation of specific muscles on skeletal growth has also been studied. Kantomaa and Ronning (1982) electrically stimulated the left lateral pterygoid muscle in ten rats for sixteen days and studied its effect on mandibular growth. The operated mandibular left side was 0.4 mm longer that the right side when measured from the condyle to mental foramen.

Treatment Options for Increased LVFH

A number of authors (Kuhn, 1968; Poulton, 1967; Watson, 1972; Pearson, (1973) have studied the influence of the direction of pull of the extraoral forces on the teeth and the palatal and occlusal planes. The conclusions drawn from these studies seemed to coincide. The direction of pull of the extraoral force, which for example is obliquely backward and upward for high pull headgear controls or even suppresses the eruption of teeth. This force vector minimizes the clockwise rotation of the mandible or even promotes a counterclockwise rotation.

Using a high pull headgear Watson (1972) showed a redirection of condylar growth in a more forward direction by inhibition or even intrusion of maxillary molar eruption. In fact, he was able to show reductions in facial convexity of 1.5 mm per year as well as a decrease in lower facial height of 0.72% per year. In addition to the dentoalveolus, vertical growth also occurs at the maxillary sutures. However, the facial sutures do not have an innate growth potential, but can only respond to the forces placed upon them. Therefore, if moderately heavy force can be delivered to the sutures, the pattern of bone apposition at those sutures may be modified. This could alter the direction of overall facial growth (Poulton, 1967; Watson, 1972; Creekmore, 1967; Wolf, 1993).

During treatment with fixed appliances another concern is the type of

mechanics used in patient's with a steep mandibular plane angles. Schudy (1963) and Ricketts (1960) both 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 3.3 mm while some of the cases showed elevations up to 8 mm. Compared to his untreated control sample of 100 growing patients with Class I and Class II high angle cases had lower molars growing vertically 1.5 mm over a period of thirty months.

Creekmore (1967) reported on sixty two untreated children. He found their lower molars growing vertically 1.59 mm over a period of 2 1/2 years. Creekmore's paper included fifty nonextraction cases treated with fixed appliances. These cases had 2.22 mm of lower molar height increase over the same 2 1/2 years time period. An increase in the posterior height of either the maxilla or the mandible produces a backward rotation of the mandible. It is possible to imagine how detrimental this change could be in patients with excessive vertical dimension (i.e., Class II high angle).

Pearson (1973) designed a study to examine whether it was possible to prevent the extrusive component of the lower molars by using extraoral forces during treatment with fixed appliances. He studied a sample of sixty cases that had steep mandibular plane angles. All of them were extraction cases and all had to wear a high pull headgear to the upper first molars. Out of sixty patients, twenty also had to wear a cervical pull headgear to the

mandibular molars to minimize extrusion during treatment. Another ten patients out of the sixty cases had to wear Class III elastics to a sliding jig that contracted the lower first molars when the maxillary head gear was worn. The remaining thirty cases were treated without mandibular headgear or jigs. These cases were designed as controls. Pearson showed that in patients with cervical pull headgear the lower molars erupted 1.5 mm less than in the control group (3.2 mm) during the period of treatment. The same was found to be true for the cases treated with the jigs to the lower molars compared to the control group where the eruption of the mandibular molars was 1.4 mm and 3.0 mm respectively.

Erbay et al. (1995) studied the effect of the Frankel FR4 on Angle Class I skeletal open bites. The result from his study showed an autorotation of the mandible due to inhibition of the maxillary suture and dentoalveolar growth, and also an increase in growth of the posterior facial height with a mean increase of 5 mm in the open bite in the treated group alouding a clockwise rotation of the mandible, compared to a mean increase of 1.4 mm in the untreated group.

Frankel and Frankel (1983) studied thirty patients with skeletal open bites treated with the Functional Regulator when compared with a group of untreated patients with skeletal open bite. They found that the mandibular plane, maxillary plane, and the ratios of UAFH to LAFH and AFH to PFH changed in the treated group to fall within the normal range, where as the

respective values for the untreated control remained unchanged or became worse. The correction of the malocclusion was due mainly to an increase in the condylar growth more than an inhibition of the maxillary skeletal and dentoalveolar growth.

Galletto et al., (1990) presented an interesting case report of an adult (19.9 years old) with a skeletal open bite that was treated nonsurgically. The authors were able to correct the malocclusion with the use of a posterior occlusal bite block in conjunction with a high pull headgear. In fact, intrusion of the maxillary molars resulted in a reduction of the lower anterior facial height and, consequently, an upward and forward rotation of the mandible. Harvold and Vargervik (1971) treated twenty patients with a Class II malocclusion using the activator appliance. They found that there was not an increase in growth of the mandible compared to the control group. There was also a reduction of forward growth of the maxilla. The mandibular alveolar process showed an increase in the height, where they found a decrease in the extrusion of the maxillary molars and concomitant alveolar bone apposition.

Sarver and Johnston (1989) compared the treatment effects of bonded versus banded rapid palatal expanders (RPE). The result of this study suggested that with the bonded RPE is possible to obtain a slight superior movement of the posterior aspect of the palatal plane and a downward and posterior movement of the anterior aspect of the maxilla so

that the downward and anterior displacement often associated with the banded RPE appliance may be negated or minimized with the bonded appliance. Therefore, bonded RPE should be used in patients with open bite tendencies.

Pearson (1978, 1986) described the use of a chin cup on growing patients with "backward rotating mandibles". His suggestion was to start the chin cup therapy twelve months before the fixed appliance and if extraction was needed, it had to be done at the beginning of chin cup therapy. He started the fixed appliance only after the bite was closed and all the teeth had erupted. The chin cup was continued throughout treatment and usually was necessary until growth ceased. With the chin cup the author was able to obtain a decrease of the Frankfort plane angle from 46 to 42 °.

Pearson (1991) in a case report with the same type of mechanics showed an actual 3 mm reduction in the LAFH for 75 mm to 72 mm in a growing patient with a severe open bite due to an excessive vertical pattern.

Iscan et al., (1992) analyzed the change with a spring loaded posterior bite block on the maxillofacial morphology comparing to a group treated with an acrylic bite block and chin cup. What they found was that in both groups there was improvement of 1 to 1.5 mm of positive open bite. In both groups they found a decrease in LAFH with autorotation of the mandible. Inhibition of vertical growth of both the upper and lower posterior teeth and a decrease in ANB was also reported. The main difference

between the two groups was that in the spring loaded posterior bite block the lower molars were intruded 1.05 mm and the angle SN-GO-AR decreased 3.09° compared respectively to 0.08 mm and 1.58 ° for the acrylic bite block and chin cup group.

Weinbach and Smith (1992) studied thirty nine patients with open bite bionators. These authors found an average change of 2.1° in the ANB angle, along with a 1.3 mm average decrease in overbite. In addition they found 0.7 mm eruption of the upper molars, compared to normal growth of 1.7 mm of eruption, by using published longitudinal standards. The authors concluded that patients with a Class II malocclusion and moderately excessive vertical dimension can be successfully treated with the open bite bionator.

Garlington and Logan (1990) studied cephalometric radiographs of twenty three Angle Class II division I cases with a mandibular plane greater than 38°. They focused on the enucleation of the mandibular second premolar and theorized that this procedure may prove beneficial for vertical control in high mandibular plane angle cases. Their findings supported this theory. They showed that by extracting the lower second premolars, the first premolars are able to drift distally, thus creating additional space anteriorly for incisors or canine rotations to occur. Mesial drift of mandibular first molars decreased posterior alveolar height and aided in creating a significant decrease in lower facial height.

Since there is often a supra-eruption of the maxillary molars associated with open bite malocclusion, Dale (1985) suggested the possibility of extracting first permanent molars rather than premolars. By removing the "posterior stop", the mandible can rotate upward and forward to help close the anterior open bite. One drawback to this treatment is lack of predictability of third molar eruption at an age which is prior to second molar eruption.

Sarver and Weissman (1995) presented a case report illustrating a different option for treatment of adult open bite malocclusions. The treatment suggested by the authors was extraction of first four premolars and crown lingual tipping of the crowns of the upper and lower incisors without any extrusion. To make this type of treatment successful the following characteristics need to be present in the patient :

1) proclined mandibular and maxillary incisors
2) little or no gingival display on smile
3) skeletal pattern should not be particularly dolichocephalic
4) anterior incisor relationship to the lip.

One of the main concerns of treatment of open bite is long term stability.

Lopez-Gavito et al., (1985) studied the stability of open bite correction in forty one white subjects that had undergone fixed orthodontic treatment and were out of retention a minimum of nine years. What the authors found was that more than 35% of the patients had a post retention open bite of 3

mm or more. Neither the magnitude of the pretreatment open bite, the mandibular plane angle, nor any other single parameter of dentofacial form proved to be a reliable predictor of post-treatment stability or relapse. Patients that relapsed showed smaller mandibular anterior dental heights, shorter upper anterior facial heights, longer lower anterior facial heights, shorter posterior facial heights, and less mandibular body growth.

Another type of approach to the open bite malocclusion, especially in adults where growth is not expected anymore, is surgical treatment. Schendel et al., (1974) analyzed the skeletal stability associated with superior repositioning of the maxilla by LeFort I osteotomy in thirty patients on recall of an average of fourteen months postoperatively. The analysis of this cases, that included open bite patients, showed that there was no significant change after fourteen months postsurgery compared with the values measured immediately after surgery. As also showed by Epker and Fish (1977) and Fish et al., (1978).

Of different opinion were Denison et al., (1989). This group compared the stability of open bite correction in twenty eight open bite patient that underwent a LeFort I procedure with twenty four patients with a positive over bite and fourteen cases with a deep bite that received the same surgery. Results showed that 42.9% of the open bite patients on recall had a significant increase in facial height, significant eruption of maxillary molars and a significant decrease of the over bite. Six of these patients exhibited

re-opening of the anterior open bite during the post-treatment period. Where the other two non open bite samples did not show any change in the past treated over bite. The superimpositions demonstrated that the relapse was due to changes in the dentoalveolar process. The authors speculate that relapse might be related to abnormal tongue position and/or hypotonic buccal musculature.

Reitzik et al., (1990) presented a new surgical approach to open bite patients which consisted of bilateral mandibular rotation osteotomy with rigid internal fixation. Their study sample consisted of sixteen non-growing patients who presented with skeletal open bite. All of the patients were treated with mandibular surgery. After one year post surgical follow up the mean closure of the gonial angle was of 9° with a mean relapse of 0.3°, and a mean mandibular plane angle change of 4.3° with a mean relapse of 0.6°

In some instances the etiology of anterior open bite can be macroglossia. Causes of macroglossia include genetic syndromes, acromegaly, hypothyroidism, and tumors. Ball and Horrocks (1995) published a case report of a patient with macroglossia that presented with a 7 mm open bite. The patient was treated by partial glossectomy and full fixed orthodontic appliances. The report showed that after tongue surgery considerable reduction of the anterior open bite occurred spontaneously prior to bonding the incisors. Two years post retention the patient's open bite was still closed.

Controversy exist as to the role of the tongue in anterior open bite. For instance, some authors suggested that the tongue is the primary cause of anterior open bite. On the other hand, other authors feel that tongue thrust is a secondary compensation for anterior open bite.

Huang et al., (1990) reported a case series of thirty three patients with open bites treated with crib therapy (26 growing, 7 non-growing). All patients showed a correction of the open bite after crib therapy. One year after treatment four of the growing patients presented with relapse. However all of the non growing patients had a stable result at one year. Huang suggested that re-education of the tongue posture via crib appliance, may prove to have a stable result in maintaining a positive over bite after treatment. This case series was similar to a case report published by Nimisen (1991).

In contrast to Huang, Frankel (1980) wrote that the tongue can not be a primary cause. In Frankel's opinion the most important goal during treatment of open bite patients is to achieve an anterior lip seal. The stability of the treatment is achieved by a balanced lip seal. In fact, the vestibular shield on the functional regulator is designed to train the lips and improve muscle tone from the first day.

AVC Appliance

One of the first articles in the literature that studied the hypothesis that teeth may be intruded in their alveoli was done by Dellinger (1967).

Dellinger placed implants in the maxilla of four experimental Macaca speciosa monkeys and used an intrusive force delivered by a spring cantilever stainless steel wire. A 360° helix mesial to the first molars was welded to maxillary first molars and first premolars. Different sizes of wire were used to obtain different magnitudes of force. Force levels of 300 g, 100 g, 50 g, and 10 g were applied for sixty days continuously to intrude the first premolars. Dellinger found that the 10 gram force was least efficient followed closely by the 300 gram force, which provided only slightly better intrusion. However severe root resorption was found with the 300 gram force. The 100 gram force caused moderate root resorption and the 10 and 50 gram forces caused only slight root resorption. In conclusion, this study showed that intrusion of teeth was possible and that 50 g of force caused the greatest intrusion with only slight root resorption.

Active vertical corrector (AVC) is an alternative approach to deliver an intrusive force to posterior teeth. The AVC uses somarium cobalt magnets embedded in separate maxillary and mandibular bite blocks to deliver an intrusive force to the maxilla and mandible via the repulsive effects of the opposing magnets as well as the conventional bite block effect. The goal of AVC therapy is to inhibit of maxillary posterior dentoalveolar development and leading to mandibular autorotation.

The force generated by a single magnet is approximately inversely proportional to the square of the distance of the gap between the two

magnets. This distance is called the air gap (Blechman, 1985). When two magnets are employed, however, the field interaction is such that the rate of decrease of force is approximately the square of the distance. That is, the smaller the air gap, the greater the force, and conversely, the greater the air gap, the smaller the force. Mandibular opening, therefore, reduces the force exponentially at a rate that is greater than linear but less than the square of the distance between the poles.

Dellinger (1986), Kiliardis et al., (1991), and Barbre and Sinclair (1991) described the results of patients with skeletal open bite treated with the magnetic active vertical corrector. The results from their study showed that the AVC produced a quick response in the dental and skeletal vertical relationships in growing individuals with an average of 3 mm of anterior open bite closure over an eight month treatment period. The bite closure was reported to be due to maxillary and mandibular molar intrusion, resulting in bite closing and mandibular autorotation. Additional significant contributions to the correction of the open bite were due to maxillary incisor eruption and lingual tipping combined with mandibular incisor lingual movement. A decrease in lower anterior facial height was also shown.

Kiliardis et al., also compared the effect of the AVC to acrylic bite block therapy. They found that with the AVC, half of the patients showed a unilateral crossbite. The group who wore the acrylic posterior bite block showed improvement in the dental and skeletal vertical relationship, but not

as extensive or as rapid as that found for the AVC group. Nevertheless, no transverse problems were noticed in the group wearing the acrylic bite blocks. The range of change of the open bite in the magnet bite block group was from 2.5 to 4.5 mm and in the acrylic bite block group from 1.5 to 2.5 mm, Most of the change was due to an intrusion of the posterior alveolar process. The authors suggested that the difference seen between these two appliances was due to the fact that with acrylic bite block, after several weeks of wearing, the patient reached a plateau of application of force. This is explained by the author as a reestablishment of the neuromuscular balance. Where instead with the magnet component the appliance is always active due to its repelling characteristics of the materials. Woods and Nanda (1988, 1991) studied and concluded the same.

Kuster and Ingervall (1992) compared the treatment results of one group treated with a spring loaded bite block and a second group treated with a bite block with repelling magnets. They found that the cases treated with the spring loaded bite block showed no evidence of intrusion of the posterior teeth, no increased mandibular growth, and no sign of anterior rotation of the mandible after one year of treatment. However, the open bite improved an average of 1.3 mm. In contrast, the group using the magnetic bite block for the three months showed twice as much mandibular prominence at pogonion. The mandibular plane also closed an average of 1.5°. The active vertical corrector also intruded the upper and lower molars

with a component of extrusion of the upper incisors. Overbite increased by 3 mm. At the end of the article the authors emphasized that the patients treated with the AVC showed a tendency towards relapse. They suggested a need for a long phase of active retention.

Barbre and Sinclair (1991) reported on a case control study of twenty five growing patients who underwent AVC treatment for open bite for an average of eight months. They reported an average of 3 mm of open bite closure. The increase in overbite was due to maxillary molar intrusion of 0.6 mm relative to palatal plane in the treated group, compare to 0.7 mm of molar eruption seen in the control group. The changes resulted in a net decrease of 1.3 mm in upper molar extrusion. Mandibular molars also showed an average of 0.4 mm of intrusion in contrast to 0.6 mm of eruption in the control. In addition part of the open bite closure was due to lingual tipping of the maxillary incisors of 2.5° relative to SN and eruption of 1.4 mm relative to palatal plane during treatment. Also the mandibular incisors showed a lingual tipping of 4°.

Kalra et al., (1989) applied a bonded bite block with magnets on ten growing patients with Class II division I malocclusion associated with mandibular retrusion and increased lower facial height. The peculiar design of the appliance had two objectives: 1) pure intrusion of the upper and lower dentition, avoiding any extrusion of upper and lower incisors by an extended wire from the bite block and bonded to the anterior upper and

lower teeth, and 2) stimulation of condylar growth by anterior discrepancy. During treatment mandibular length increased 3.2 mm as compared with 0.8 mm in the control group, the upper and lower posterior teeth intruded an average of 1.5 mm each, and the mandibular plane angle decreased 1.3°. The authors also reported that when the appliances were removed a 4 mm posterior open bite was seen. They concluded that since the teeth had intruded only the gum pads covering the unerupted second molars were touching. This led to some relapse of the intrusion.

STATEMENT OF THESIS

The purpose of this investigation was to evaluate the relative contributions of two skeletal and four dental components to open bite correction in two phase non extraction treatment for open bite malocclusion. Twenty-nine subjects were selected by one orthodontist from his private practice in Fort Wayne, Indiana. All subjects had at least zero or less vertical incisor overlap and no incisor contact at the start of treatment, along with adequate initial, end of phase 1, and deband lateral cephalog. Each subject in the treated group was matched by age, sex, and treatment time with an untreated subject from in the Broadbent Bolton Collection, Cleveland, Ohio.

A cephalometric analysis, which utilized six linear and two angular measurements, was used to evaluate dental and skeletal changes during phase 1 (T1-T2) and phase 2 (T2-T3) and over the total treatment period (T1-T3). The analysis isolated tipping and bodily tooth movements of the upper and the lower incisors and assessed vertical skeletal changes in the anterior region of the maxilla and mandible.

METHODS AND MATERIALS

The sample consisted of twenty nine nonextraction subjects treated with the AVC appliance for open bite malocclusion selected by Dr. Eugene Dellinger from his private practice in Fort Wayne, Indiana. All subjects had an overbite of 0 mm or less before treatment as assessed on the pre-treatment cephalogram. All the treated subjects also had cephalograms before treatment (T1), after AVC treatment (T2), and at the end of fixed orthodontic treatment (T3). The study subjects were matched by sex, age, and treatment time to twenty nine untreated individuals enrolled in the Bolton Study, Cleveland, Ohio.

Cephalometric Analysis

All radiographs were traced on 0.003" matte acetate with a 0.5 mm mechanical lead pencil. A cephalometric analysis was used which contained six linear and two angular measurements (Kishiyama, 1987) (see Figure 1). The linear measurements were made to the nearest 0.01 mm using a customized computer program (Geocalc; Mensforth and Haver, Cleveland State University). All angular measurements were made to the nearest 0.5° using Ricketts "dome" orthodontic template.

The cephalometric analysis was used to measure skeletal and

dentalchanges from time one to time two, and from time two to time three, for both the Treated (T1-T2-T3) and the Control groups (C1-C2-C3).

The three cephalograms for each subject were labeled as follows:

T1 = Pre-treatment film	C1 = Time 1 control film
T2 = Post A.V.C. appliance film	C2 = Time 2 control film
T3 = Deband film	C3 = Time 3 control film

All measurements were made from a constructed fiducial horizontal reference line (Parker, 1990). Bilateral anatomical landmarks were bisected and the midpoints calculated. This reduced landmarks to their midsagittal value allowing identification of fourteen points according to Parker (1990) The landmarks traced were:

1. Sphenoethmoidal Junction (SE)
2. *Foramen Rotundum in the Pterygomaxillary Fissure
3. Inferior-most Point of the Pterygomaxillary Fissure
4. *Three (3) mm Above Orbitale
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. Occlusal Point of the First Maxillary and Mandibular Molars
10. Incisal Edge of the Lower Incisor
11. CR of the Lower Incisor

12. Articulare (AR)
13. Gonion (GO)
14. Menton (ME) and Symphyses

*Used to construct the fiducial reference line on the time one tracing and transferred to the time two and time three tracings by superimposition on anterior cranial base landmarks

Landmarks were traced from T1 (or C1), T2 (or C2) and T3 (or C3) radiographs with the exception of the upper and lower incisors, molars and the fiducial reference plane. The CR for the incisors was arbitrarily set at 40% of the distance from the alveolar crest to the root apex. A template was used to transfer the CR point from the Time 1 to Time 2, and from T1 to T3 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 (or C1). The CR of the upper and lower incisors was transferred to the T2 and T3 tracings by registration on the incisal edge.

The sphenoethmoidal junctions and the anterior cranial base were superimposed to evaluate anatomical change from Time one (T1) (C1) to Time two (T2) (C2), and from Time one (T1) (C1) to Time Three (T3) (C3) . After landmarks were traced, a fiducial horizontal reference line was constructed as described by Baumrind (Baumrind and Miller 1980). Superimposition of the subsequent radiographs on the spenoethmoidal junction and the anterior cranial base the fiducial line was transferred to the Time 2 and Time 3 cephalometric tracings (Elmejian 1959).

Six linear distances were measured from the horizontal fiducial reference line, which was defined on the T1 tracing as a line between the pterygoid point to point 3 mm above orbitale. The T1 reference line was transferred to the subsequent tracings by superimposition on the sphenoethmoidal junction and the anterior cranial base. Linear measurements were made to the nearest 0.1 mm using a custom software computer program (Geocalc by Mensforth and Haver, Cleveland State University). Angular measurements were made to the nearest 0.5 degree using a Ricketts orthodontic template (Dome Manufacturing Co., Tarzana, CA).

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

Measurement 1 (M_1): Distance from the reference line to anterior nasal spine (ANS)

Measurement 2 (M_2): Distance from the reference line to the center of resistance (CR) of the maxillary incisor

Measurement 3 (M_3): Distance from the reference line to the incisal edge of the maxillary incisor

Measurement 4 (M_4): Distance from the reference line to the incisal edge of the mandibular incisor

Measurement 5 (M_5): Distance from the reference line to the center of resistance (CR) of the mandibular incisor

Measurement 6 (M_6): Distance from the reference line to Menton (ME)

Seven variables were obtained from these linear measurements and used to assess anterior vertical changes. These variables were as follows (see Fig. 2):

1. Maxilla (MXSK): Maxillary skeletal change was evaluated by change in M1, distance from the reference line to ANS.

2. Upper Extrusion (BUI): Bodily movement of the upper incisor evaluates the amount of extrusion by subtracting M1 from M2.

3. Upper Tipping (TUI): Vertical change of the upper incisor due to tipping was evaluated by subtracting M2 from M3.

4. Lower Tipping (TLI): Tipping movements of the mandibular incisor was evaluated by subtracting M4 from M5.

5. Lower Extrusion (BLI): Bodily extrusion of the mandibular incisor was evaluated by subtracting M5 from M6.

6. Mandible (MNSK): Mandibular skeletal change was evaluated by subtracting M1 from M6.

7. Overbite (OB): Change in overbite was evaluated by subtracting M4 from M3.

The mandible (MNSK) measurement includes the factors which effect the displacement and vertical position of the mandible. By definition, molar extrusion accompanies increased mandibular skeletal change. Changes in the mandibular plane angle as well as in the gonial angle influence the magnitude of MNSK. By measuring the difference in the angle formed by the intersection of the mandibular plane with sella-nasion plane, the changes in the mandibular plane angle at T1 (CI), T2 (or C2), T3 (or C3) were compared.

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. 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 .

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

Variable: GO
+ = gonial angle became more acute
- = gonial angle became more obtuse

Variable: MPA
+ = mandibular plane became more closed
- = mandibular plane became more open

Statistics

The purpose of this study was to test the effectiveness of the AVC appliance in correcting open bite malocclusion. The use of the cephalometric analysis adopted in this study allowed skeletal change to be differentiated from dental change. Dental changes were also subdivided into bodily or tipping movements. Changes due to normal growth can be estimated from the mean changes in the untreated, matched control group at the different time period. Changes due to treatment can be estimated by subtracting the mean treatment changes at each time period.

Data analysis was performed using the Statistical Package for the Social Sciences (SPSS/PC+ City State) in the Orthodontic Department at Case Western Reserve University. Descriptive statistics (means and standard deviations) for each of the seven linear and two angular measurements are shown in Table 1. In accordance with the matched design changes in each of the variables were calculated by subtracting the difference between T1 (C1) and T2 (C2), between T2 (C2) and T3 (C3), and between T1 (C1) and T3 (C3) for each individual in each group. Means and

standard deviations for the changes in each variable were then determined. Between group (T1-T2-T3 vs C1-C2-C3) differences were examined using a paired t-test with Bonferroni correction factor. Bonferroni correction is determined by dividing the level of significance desired (0.05) by the total number of tests (27) to establish a corrected level of significance. The alpha value was set at 0.05. A p value equal or lower than 0.002 was used to assess statistical significance.

Error Assessment

To evaluate the degree of investigator measurement error, ten radiographs were randomly selected and the seven linear and two angular variables used in this study were repeated. These second set of measurements were then compared to the first set and reliability coefficients calculated.

Tracing error was evaluated in a similar manner.

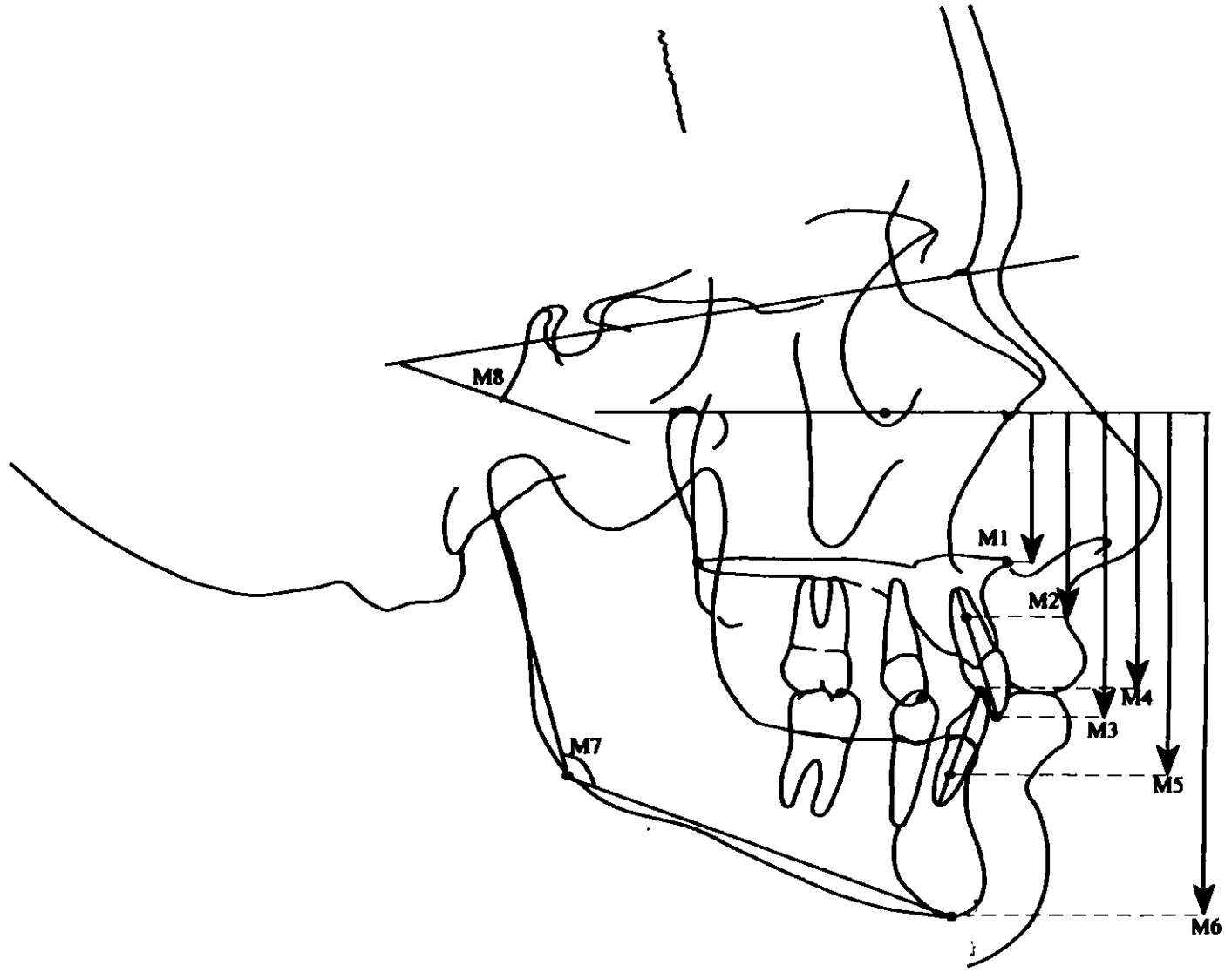


Figure 1- Measurements used to derive variables (see explanation of M1 through M8 on page 38)

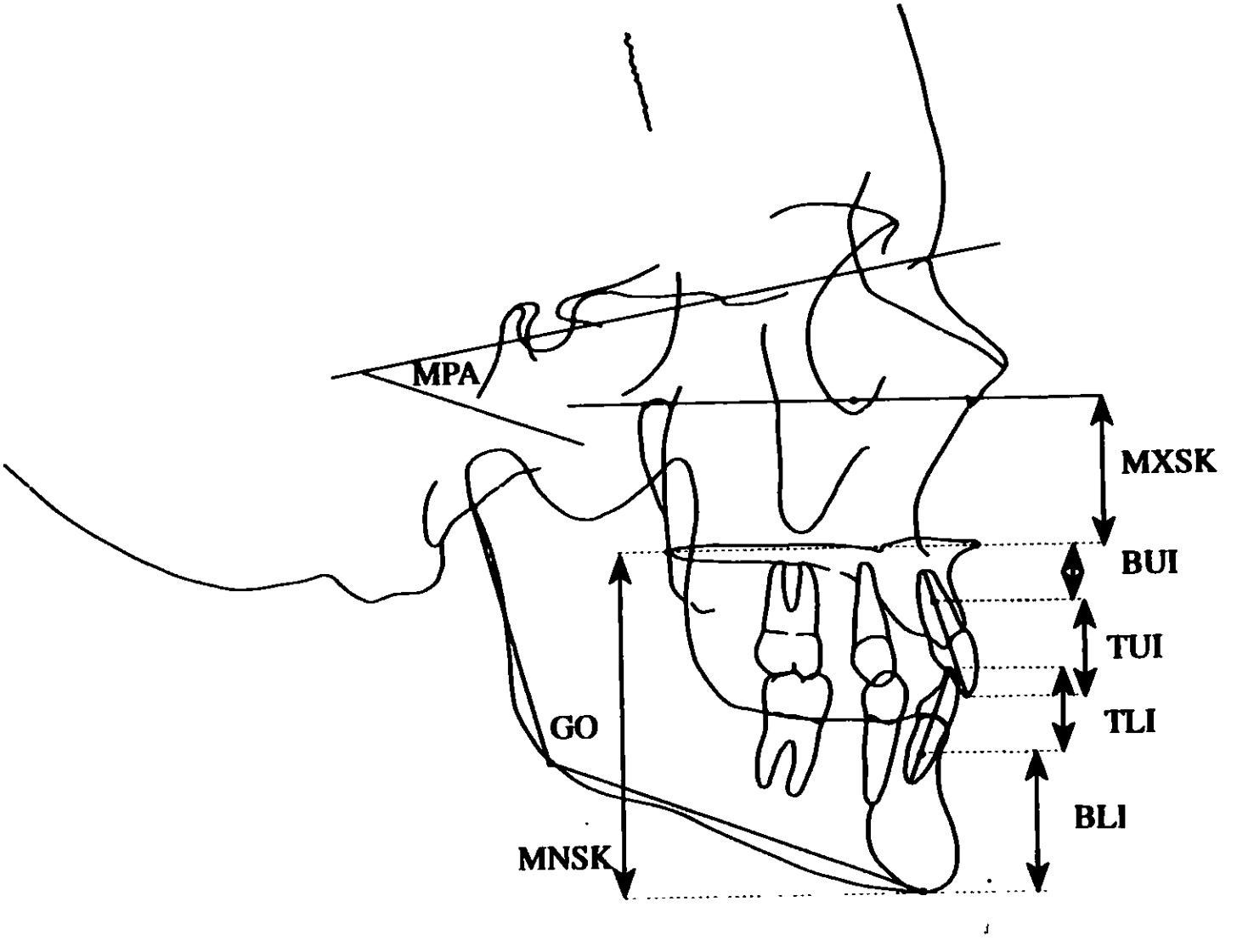


Figure 2- Variables measured (see explanation of the variables on page 39)

RESULTS

Patient Sample Description

Each group, control and treated, consisted of twenty nine subjects , of which twenty three were females and six males (see Table 1). The treated and control subjects were matched by sex, age, and time interval between records. The mean age at Time 1 for the treated group and control group was 11.1 years and 11.0 years, respectively. The mean time interval between Time 1 and Time 2 was eight months for the treated group and nine months for the control group. The mean interval time from Time 2 to Time 3 for both the treated and the control group was 3.6 years.

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

	TREATED	CONTROL
# OF FEMALE	23	23
# OF MALE	6	6
MEAN AGE: TIME T1	11yr 1mo ± 3yr 1mo	11yr 0mo ± 3yr 1mo
MEAN AGE: TIME T2	11yr 9mo ± 3yr 0mo	11yr 9mo ± 3yr 0mo
MEAN AGE: TIME T3	15yr 3mo ± 2yr 6mo	15yr 3mo ± 2yr 6mo

Control Versus Treated Group at T1

Four variables were significantly different ($p \leq 0.002$) between treatedand control group at T1 (see Table 3). The mean values for the variables MNSK and GO were greater in the treated group compare to the control group. The value for TUI in the treated group was significantly smaller than the control. Overbite was a negative number for the treated group (OB -2.2 mm) compared with a positive value (OB +3.4 mm) for the control group.

The Control Group

Over bite increased in the control group an average of 0.9 mm from Time 1 to Time 2 and decreased an average of -0.8 mm from Time 2 to Time 3 (see Table 2-5-6-7). The mean values from Time 1 to Time 2 and from Time 2 to Time 3 for values MXSK, BUI, TLI and BLI moved in a positive direction towards the occlusal plane. The mean values from Time 1 to Time 2 and from Time 2 to Time 3 for TUI, MNSK, GO and MPA moved away from the occlusal plane.

Values for this group of control subjects were also compared to the values from the control group used by Parker (1990), Dietrich (1992) and Damon (1995). The average per year change for each study's control group is shown in Table 4. Interesting no significant differences were found among the four groups except for the gonial angle. In the present study the gonial angle showed 0.5° more closure per year.

Table 2.--Means and Standard Deviations at T1, T2 and T3 for Treated and Control groups

VAR.	Tx_1 MEAN	Tx_1 STD	Tx_2 MEAN	Tx_2 STD	Tx_3 MEAN	Tx_3 STD	C_1 MEAN	C_1 STD	C_2 MEAN	C_2 STD	C_3 MEAN	C_3 STD
MXSK	22.0	± 4.0	22.7	± 3.8	25.2	± 3.9	24.9	± 4.0	26.0	± 3.8	28.4	± 4.1
BUI	8.2	± 3.1	9.0	± 2.9	11.2	± 2.5	5.9	± 2.4	6.8	± 2.5	8.2	± 2.8
TUI	18.4	± 2.0	18.7	± 1.6	17.8	± 4.0	21.0	± 1.9	20.9	± 1.9	20.7	± 1.8
TLI	16.5	± 1.2	17.1	± 1.1	17.5	± 4.3	15.9	± 1.9	16.0	± 1.9	16.2	±1.8
BLI	21.6	± 3.5	22.4	± 3.1	25.5	± 2.8	19.6	± 3.4	20.3	± 3.1	22.4	± 3.5
MNSK	67.1	± 6.4	67.2	± 6.0	71.2	± 5.2	58.7	± 5.4	59.8	± 5.6	64.1	± 5.9
OB	-2.2	± 1.6	0.17	± 1.8	0.93	± 1.5	3.4	± 2.7	4.4	± 2.3	3.6	± 2.8
GO	129.6	± 6.8	129.6	± 7.2	128.7	± 7.7	125.0	± 5.1	124.6	± 5.3	124.0	± 6.2
MPA	37.1	± 5.1	36.3	± 5.0	36.7	± 5.7	34.0	± 4.3	33.7	± 4.9	33.3	± 5.2

Table 3.--Comparison between the Treated and the Control groups at Time I

VAR.	Tx_1 MEAN (STD)	C_1 MEAN (STD)	P-VALUE	SIG.
MXSK	22.0 (±4.0)	24.9 (±4.0)	0.007	NS
BUI	8.2 (±3.1)	5.9 (±2.4)	0.007	NS
TUI	18.4 (±2.0)	21.0 (±1.9)	0.000	*
TLI	16.5 (±1.2)	15.9 (±1.9)	0.201	NS
BLI	21.6 (±3.5)	19.6 (±3.4)	0.049	NS
MNSK	67.1 (±6.4)	58.7 (±5.4)	0.000	*
OB	-2.2 (±1.6)	3.4 (±2.7)	0.000	*
GO	129.6 (±6.8)	125.0 (±5.1)	0.001	*
MPA	37.1 (±5.1)	34.0 (±4.3)	0.004	NS

Table 4.--Comparison between the changes per year for the control groups in the current investigation, Parker's 1990 study, Dietrich's 1992 study and Damon's 1995 study

VARIABLE	PARKER 1990 CONTROL MEAN VALUE	DIETRICH 1992 CONTROL MEAN VALUE	DAMON 1995 CONTROL MEAN VALUE	BAZZUCCHI1996 CONTROL MEAN VALUE
MXSK	0.7	0.7	0.7	0.8
BUI	0.3	0.3	0.5	0.5
TUI	0.0	0.0	0.0	0.0
TLI	0.0	0.0	0.0	0.0
BLI	-0.8	-0.6	-0.6	0.6
MNSK	1.2	0.8	1.1	1.2
OB	-0.1	0.1	0.0	0.2
GO	-0.5	-0.4	-0.6	-1.0
MPA	0.2	0.2	0.3	0.6
Age Range:	11y 2m -14y 4m (38 mo)	12y 10m-16y 2m (40 mo)	12y 11mo-16y 0m (38 mo)	11y 0m-15y 3m (51 mo)

The Treated Group

The treated group showed 2.4 mm and 0.7 mm of bite closure from Time 1 to Time 2 and Time 2 to Time 3, respectively (see Table 2-5-6-7). From Time 1 to Time 2 MXSK, BUI, TUI, TLI, BLI, MNSK, and GO moved in a positive direction for open bite closure. The same was true from Time 2 to Time 3 for all of these variables except TUI (-0.8 mm).

Control Versus Treated Group from T1 to T2

Overbite in the treated group increased by 2.4 mm compared to an increase of 0.9 mm in the control group during the same period of time. The combination in the treated group of minimal change in mandibular skeletal height MNSK (0.1 mm) from Time 1 to Time 2 and favorable changes in the variables BUI, TUI, TLI, and BLI accounted for 2.3 mm of open bite closure. In the control group favorable changes in the variables BUI, and BLI of 2 mm towards the occlusal plane were partially offset by an increase in lower mandibular skeletal height (MNSK) of 1 mm. The net result was an increase in overbite of 0.9 mm in the control sample (see Table 7 and Figure 5).

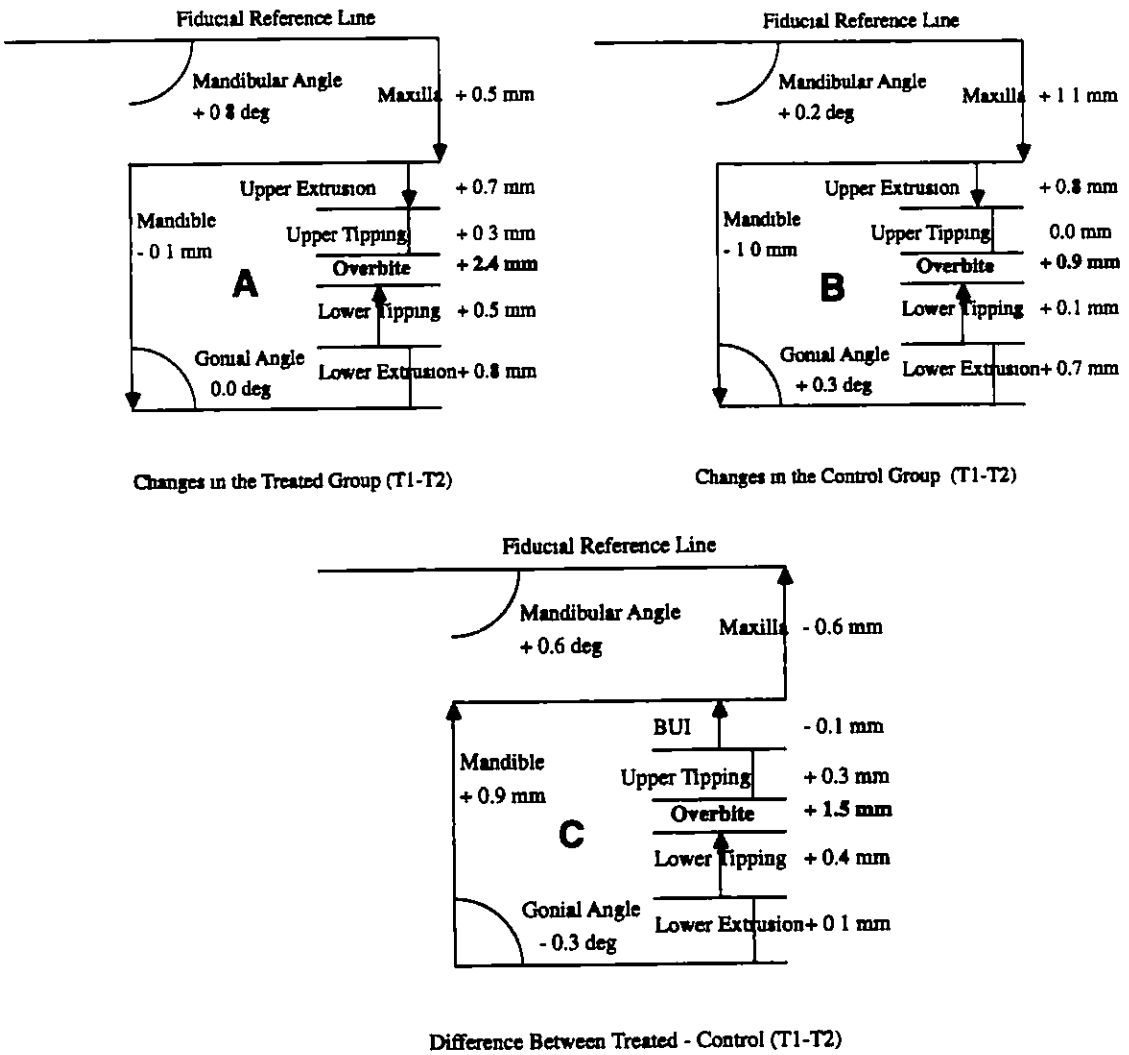


Figure 3. *A* shows a good control of the MNSK value and lingual tipping of the upper and lower incisors, compare to the control group *B*. *C* shows the net changes due to treatment only.

Table 5.--Comparison of the Changes from Time 1 to Time 2 for the Control and Treated groups

VARIABLE	TREATED MEAN	TREATED STD	CONTROL MEAN	CONTROL STD	P-VALUE	SIG.
MXSK	0.5	± 0.8	1.1	± 1.6	0.128	NS
BUI	0.7	± 1.3	0.8	± 0.9	0.871	NS
TUI	0.3	± 1.2	-0.0	± 0.6	0.164	NS
TLI	0.5	± 0.7	0.1	± 0.8	0.052	NS
BLI	0.8	± 1.3	07	± 1.0	0.971	NS
MNSK	0.1	± 1.9	1.0	± 1.3	0.030	NS
OB	2.4	± 1.8	0.9	± 1.8	0.007	NS
GO	0.0	± 1.8	-0.3	± 3.9	0.629	NS
MPA	-0.8	± 1.3	-0.2	± 1.0	0.129	NS

Control Versus Treated Group from T2 to T3

During the fixed appliance phase, overbite in the treated group increased by 0.7 mm. This change favorably compared to the control group that registered a -0.8 mm decrease in overbite during the same time period (see Table 6 and Figure 4). In the treated group the total extrusion or eruption of the upper and lower incisors accounted for 5.1 mm of vertical change. The control group had a total vertical change of 3.4 mm during the same period of time. The mandibular skeletal height in the treated group was maintained from Time 2 to Time 3 (MNSK = 4.0 mm) while the untreated control group showed 4.2 mm of change. Tipping of the upper incisors forward resulted in bite opening effect of -0.8 mm (TUI = -0.8 mm). However change in TUI was not significantly different from the controls which showed a change of -0.1 mm for the TUI variable.

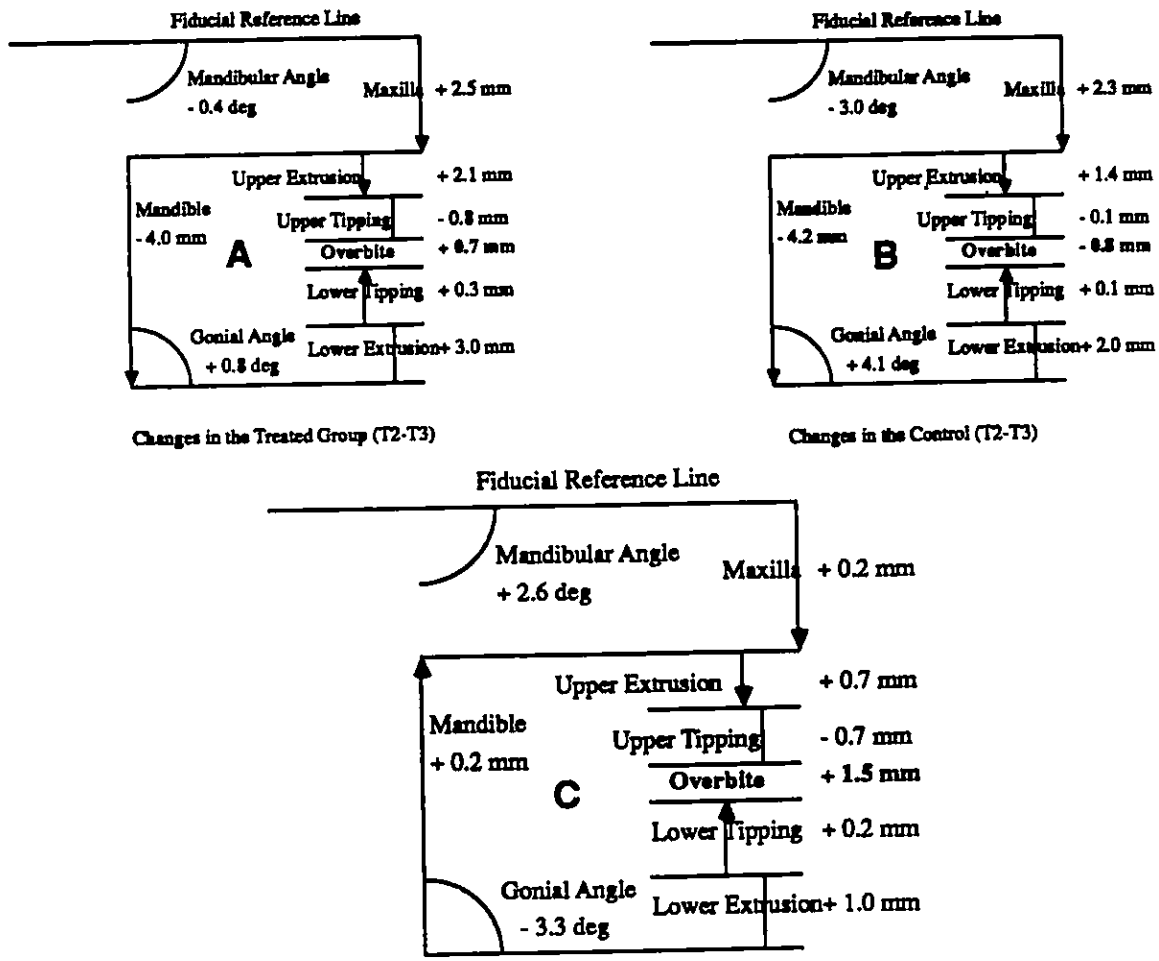


Figure 4. *A* shows greater extrusion of the upper and lower incisors in the treated group during the fixed appliance, compare to the control group *B* during the same period of time. *C* shows the net changes due to treatment only.

Table 6.--Comparison of the Changes from Time 2 to Time 3 for the Control and Treated groups

VARIABLE	TREATED MEAN	TREATED STD	CONTROL MEAN	CONTROL STD	P-VALUE	SIG.
MXSK	2.5	± 1.9	2.3	± 3.0	0.785	NS
BUI	2.1	± 2.1	1.4	± 1.5	0.171	NS
TUI	-0.8	± 3.6	-0.1	± 0.6	0.359	NS
TLI	0.3	± 4.0	0.1	± 0.8	0.740	NS
BLI	3.0	± 1.8	2.0	± 2.2	0.082	NS
MNSK	4.0	± 2.9	4.2	± 3.1	0.792	NS
OB	0.7	± 1.8	-0.8	± 2.0	0.004	NS
GO	-0.8	± 2.7	-4.1	± 1.8	0.371	NS
MPA	0.4	± 1.9	3.0	± 1.8	0.460	NS

Overall Changes of Control Versus Treated Group from T1 to T3

The overbite showed a highly statistical significant (p value 0.000) amount of open bite closure (OB = 3.1 mm) (see Table 7 and Figure 5). The combination of the extrusion of the upper and lower incisors (BUI and BLI) was equal to 6.7 mm. The mandibular skeletal height also showed a change of only 4.1 mm compared to the control group which changed 5.3 mm. If the total amount of growth of this variable in the control is subtracted from the treated group, the treated group has a 3.6 mm of growth towards the occlusal plane. The mean values for BUI, BLI, and MNSK were lower in the Treated group than in the control group. Although the differences were not statistically significant , the combined effects of these values resulted in a clinically observed increase in overbite.

The upper incisors showed labial tipping in the treated group (-0.5 mm) but not significantly different from the control group (-0.2 mm). The mandibular plane angle showed a good control on the vertical dimension in the treated group (-0.3 °) from Time 1 to Time 3 compared to the control group (2.7°) for the same period of time.

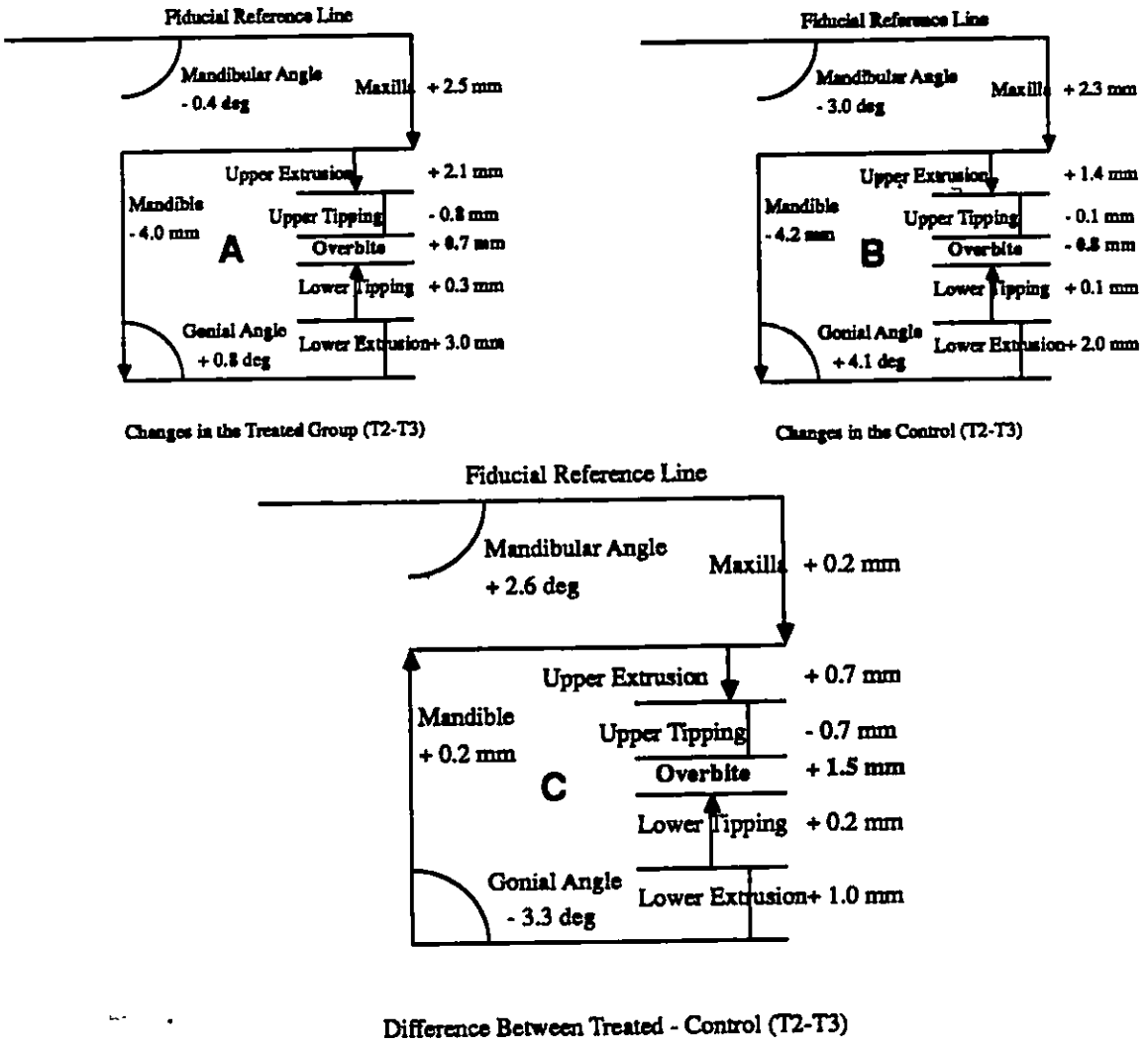


Figure 4. *A* shows greater extrusion of the upper and lower incisors in the treated group during the fixed appliance, compare to the control group *B* during the same period of time. *C* shows the net changes due to treatment only.

Table 7.--Comparison of the Changes from Time 1 to Time 3 for the Control and Treated groups

VARIABLE	TREATED MEAN	TREATED STD	CONTROL MEAN	CONTROL STD	P-VALUE	SIG.
MXSK	3.0	± 2.1	3.5	± 3.2	0.527	NS
BUI	2.9	± 2.7	2.2	± 1.6	0.298	NS
TUI	-0.5	± 3.8	-0.2	± 0.7	0.713	NS
TLI	0.9	± 4.0	0.2	± 0.7	0.357	NS
BLI	3.8	± 2.3	2.8	± 2.5	0.116	NS
MNSK	4.1	± 3.7	5.3	± 3.5	0.289	NS
OB	3.1	± 2.0	0.1	± 2.9	0.000	*
GO	-0.8	± 3.1	-4.4	± 1.8	0.300	NS
MPA	-0.3	± 1.9	2.7	± 1.8	0.381	NS

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DISCUSSION

The purpose of this study was to evaluate the anterior vertical dental and skeletal changes that occur when the AVC appliance is used to correct open bite in a sample of twenty nine selected subjects. The cephalometric analysis used in this study enabled the investigator to distinguish skeletal change from dental change, and further subdivided dental changes into bodily and tipping movements. The overbite correction achieved at the end of phase I treatment (T2), was also evaluated after phase 2 treatment with fixed appliance (T3). The results demonstrated that the total amount of open bite closure was 3.1 mm from T1 to T3, with 2.4 mm occurring during the AVC treatment (T1-T2) and 0.7 mm occurring during the fixed appliance phase (T2-T3). A more detailed analysis of the relative contribution of each variable to open bite correction follows.

Skeletal Changes

There were no statistically significant changes between the control and experimental groups for Maxillary Skeletal (MXSK) or Mandibular Skeletal (MNSK) variables. The mean value for MNSK showed almost no change from T1 to T2 (MNSK = 0.1 mm) (see Table 5 and Figure 3). The control group showed a change of 1.0 mm during the same period of time.

Such change in the control group is in agreement with McNamara (1981a) who reported that the lower facial height typically increases 1.0 mm per year.

The reduction in vertical growth of the mandible achieved during phase 1 was maintained during phase 2 (T2 - T3) as shown by the mean values in the treated group for the variable MNSK = 4.0 mm and in the control the mean of the MNSK variable was 4.2 mm (see Table 6 and Figure 4). This allowed for 4.1 mm of overall (T1 -T3) growth in the mandibular skeletal height in the treated group compared to the 5.3 mm in the control group (see Table 7 and Figure 5). The treated group showed a relative decrease of 1.2 mm in overall (T1 to T3) mandibular skeletal height compared to the control group. This findings is more significant when viewed in light of previous studies. For example Dietrich (1992) studied open bite patients treated with four first bicuspid extraction and found a significant increase in mandibular skeletal height during treatment. A total of 1.2 mm of increase mandibular vertical growth was seen in the treatment group. Damon (1995) studied the skeletal and dental changes in deep bite patients treated with the Tweed technique and had first bicuspid extractions. In this study, there was no significant change for the maxillary skeletal or mandibular vertical height at the end of treatment compared to the control. Damon showed that the Tweed technique controlled mandibular skeletal

height and no significant change in mandibular skeletal height was seen. The actual number found in the present study are vary close to the number reported by Barbre and Sinclair (1991). Interestingly Barbre and Sinclair reached a different conclusion from similar results. The control group used by Barbre and Sinclair was matched by sex, age, and treatment time to the treated group. However the statistical analysis used "involved the use of means and standard deviations for each parameters followed by a student's t test for independent samples to determine differences between group means". The use of a statistical test designed for independent samples is not appropriate for matched sets. Some of the other studies did not have a sufficient sample to draw any statistical conclusion (Kiliardis et al, 1991; Dellinger, 1986; Kuster and Ingervall, 1992). All of the other articles that have studied the effects of the AVC appliance in the treatment of open bite have used an animal model (Woods and Nanda, 1988).

The mean maxillary skeletal change was not different from T1 to T3 between the treated and control group (3.0 and 3.5 mm, respectively). We can assume that the maxillary skeletal growth in the treated group was not affected by the appliances used in this study compared to the untreated group.

Dental Changes

The vertical analysis used in the present study enable the investigator to separate bodily movements of the upper and lower incisors from tipping

movements.

In the present study there were no significant statistical differences in the amount of either bodily or tipping movement of the upper and lower incisors in the treated group compared to the control group. The bodily movement (BUI and TUI) of the upper and lower incisors were one of the key factors that permitted the correction of the overbite but the values per se were not statistically significant compared to the control group. From T1 to T2 the mean value of the bodily movements of the upper and lower incisors was 1.5 mm (BUI + BLI) (see Table 5 and Figure 3). During T2 to T3 the sum of BUI and BLI was 5.1 mm (see Table 6 and Figure 4). There was a mean total change in the extrusion of the upper and lower incisors from T1 to T3 of 6.7 mm compared to the mean value of 5.0 mm for the control group from T1 to T3 (see Table 7 and Figure 5).

There was no difference in the tipping of the lower and upper incisors, even compared to the mean values. The mean value for BUI and BLI from T1 to T3 were 2.9 mm and 3.8 mm, respectively, compared to the mean values for TUI and TLI of 2.2 mm and 2.8 mm, respectively, for the control group during the same period of time.

In contrast, Dietrich (1992) did not show any extrusion of the upper and lower incisors. In his study there was a net change of 2.9 mm of tipping of the upper and lower incisors that resulted in open bite correction. Two thirds of this tipping was due to upper incisor movement. Extraction sites

provide space for lingual tipping of the upper and lower incisors during open bite closure. In this current study there were no extractions. Therefore the only dental compensation seen was bodily extrusion of both upper and lower incisors. Damon (1995) showed upper and lower intrusion of 4.3 mm in his sample of deep bite patients. There was 0.1 mm of labial tipping of the lower incisors and 0.3 mm of lingual tipping of the upper incisors. This may also be explained by the probable use of Class II elastics.

This is the same amount of negative labial tipping found in this current study, but these results are most likely due to the probable use of Class III elastics.

Angular Changes

The changes in the angular variables (GO - MPA) were not statistically significant between the control and treated group during T1 to T2 and T2 to T3. Clinically it is difficult to maintain MPA during treatment with fixed appliances. From T1 to T2 MPA decreased -0.8° and from T2 to T3 a mean decrease of 0.4° was seen (see Table 5-6 and Figure 3-4). The overall change for the treated group from T1 to T3 for the mean value of the MPA was -0.3° compared to the mean value of the untreated group of 2.7° (see Table 7 and Figure 5). This result indicates that vertical control of growth in the treated group during both the AVC phase and the fixed appliance phase was excellent.

The gonial angle (GO) did not show any significant change from T1 to

T2 with a mean value of 0.0° and a mean change from T2 to T3 of -0.8° (see Table 5-6 and Figure 4-8-10-14).

A previous report by Damon (1995) demonstrated that mandibular plane angle can be controlled during treatment. Damon showed a decrease of 0.3° in the gonial angle in the treated group. Dietrich (1992) also showed a decrease of 0.5° in the gonial angle. The mandibular plane angle in Deitrich's study opened 0.3° with a negative treatment effect on his patient sample.

Overbite Correction

Overbite increased in the treated group from T1 to T2 by 2.4 mm. This compared to a 0.9 mm increase in overbite in the control group (see Table 5 and Figure 3). Therefore, the treatment effect was an increase of 1.5 mm. This correction was due to upper and lower incisor tipping of 0.7 mm (TUI and TLI) and relative closure of the mandibular plane angle of 0.9° and +1 mm of relative decrease of mandibular skeletal height. From T2 to T3 the open bite correction in the treated group was 0.7 mm compared to a decrease of 0.8 mm in the untreated group (see Table 6 and Figure 4). This resulted in a total treatment effect of 1.5 mm of open bite closure. During the fixed appliance treatment the upper and lower incisor extrusion (BUI, BLI) accounted for 1.7 mm of open bite correction. The lower incisors also improved the open bite by 0.2 mm of lingual tipping (TLI), in contrast, the upper incisor tipping (TUI) showed 0.7 mm of labial tipping. The tipping

changes could be due to Class III elastic wearing during treatment. The overall change from T1 to T3 showed a open bite closure of 3.1 mm compared to the 0.1 mm of closure in the control sample (see Table 7 and Figure 5). When changes in the control group are subtracted from changes observed in the treated group the net difference in bodily incisors movement (BUI and BLI) was 1.7 mm. Lingual tipping of the lower incisors (TLI) added an additional 0.7 mm. Labial tipping of the upper incisors (TUI) decrease overbite of -0.3 mm. The remaining increase in overbite was the result of a relative decrease in mandibular skeletal height of 1.2 mm.

Such data suggested than during the AVC appliance (T1-T2) correction of the open bite was due to control of the mandibular skeletal height (MNSK) with minimal lingual tipping of the upper and lower incisors (TUI-TLI). In contrast during the fixed appliance (T2-T3) phase the key factor was extrusion of the upper and lower incisors (BUI-BLI).

Dietrich (1992) showed in his study that treatment with fixed appliances and extraction of four first bicuspid resulted in tipping of the upper and lower incisors to produce a positive overbite at the end of treatment.

SUMMARY AND CONCLUSIONS

The purpose of this investigation was to evaluate in two phase non extraction treatment for open bite malocclusion the relative contributions of two skeletal and four dental components to open bite correction. Twenty-nine subjects were selected by Dr. Eugene Dellinger from his private practice in Fort Wayne, Indiana. All subjects had zero vertical incisor overlap and no incisor contact at the start of treatment, along with adequate initial, end of phase 1, and deband lateral cephalogram. Each subject in the treated group was matched by age, sex, and treatment time with an untreated subject enrolled in the Broadbent Bolton Collection, Cleveland, Ohio.

A cephalometric analysis (Parker 1990) which utilized six linear and two angular measurements as used to evaluate dental and skeletal changes during phase 1 and phase 2. The analysis isolated tipping and bodily tooth movements of the upper and the lower incisors and assessed vertical skeletal changes in the anterior region of the maxilla and mandible.

Analysis of the data revealed that :

1. No statistically significant changes in any variables were found during phase 1 or phase 2.

2. Overbite was significantly improved ($p \leq 0.002$) when both phase 1 and phase 2 changes were pooled (T1-T3).

3. Most of the clinically significant open bite correction during treatment with the AVC appliance was achieved by relative decrease of the mandibular skeletal height and lingual tipping of the upper and lower incisors. During phase 2 treatment extrusion of the upper and lower incisor was clinically significant for correction of the anterior open bite.

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