CASE WESTERN RESERVE UNIVERSITY

SCHOOL OF DENTISTRY

GRADUATE STUDIES

We hereby approve the thesis of

C.P. Dietrich III

candidate for the degree Master of Science

in Dentistry.

Signed: _____ (Chairman)

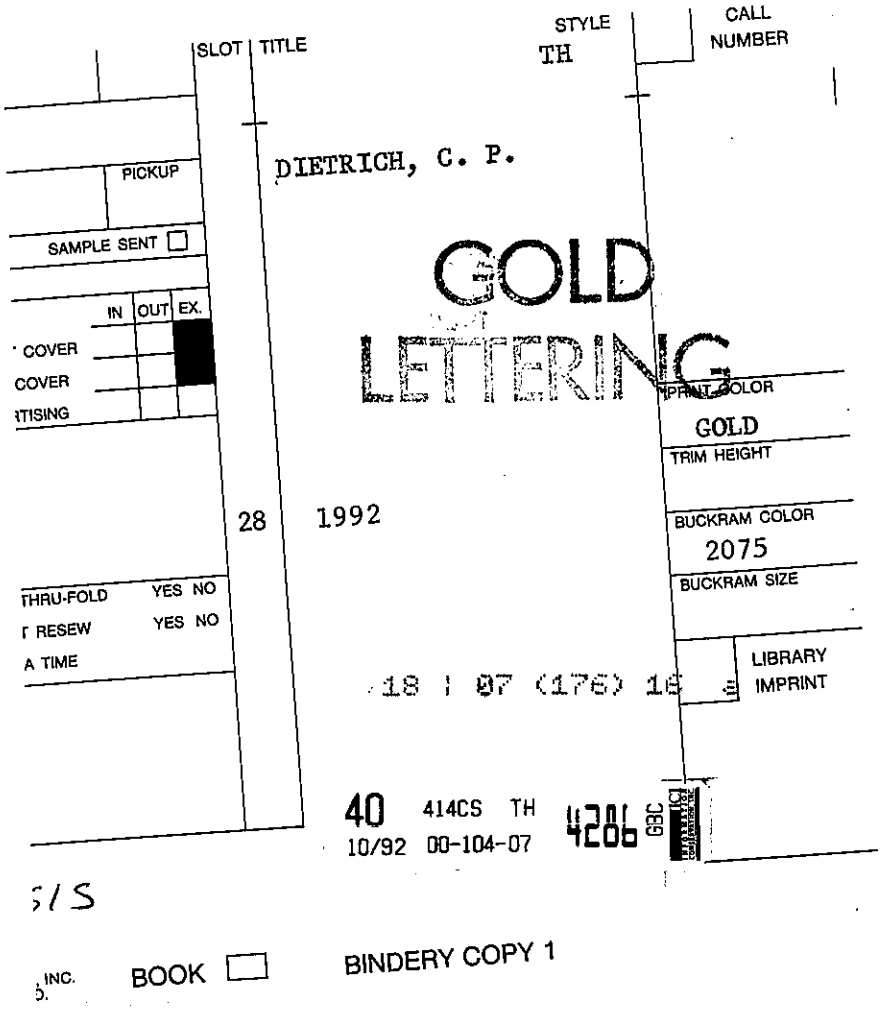
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VERTICAL CORRECTION OF OPEN BITE MALOCCLUSIONS

Abstract

by

CARL PHILLIP DIETRICH III

The purpose of this investigation was to determine the relative contribution of various skeletal and dental components in open bite correction. Thirty-one patient records were selected from among the completed cases of the Department of Orthodontics at Case Western Reserve University. The cases were selected on the basis of zero vertical incisor overlap and no incisor contact at the start of treatment. In addition, all patients had adequate initial and deband radiographs. All patients had been treated with four first bicuspid extractions and fixed edgewise appliances. The treated group was matched by age, sex and treatment time with a sample of untreated open bite patients from the Bolton Collection, Cleveland, Ohio.

A cephalometric analysis (Parker 1990) which utilized six linear measurements and two angular measurements was used 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 from bodily movements of the upper and the

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Submitted in partial fulfillment of the requirements

for the Degree of Master of Science in Dentistry

Department of Orthodontics

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lower incisors and assessed vertical skeletal changes in the maxilla and the mandible.

The following observations were made by analyzing the data:

1. Most of the open bite correction was achieved by lingual tipping of the upper and the lower incisors.

2. Lower facial height and mandibular plane increased slightly, having a negative effect on open bite correction.

3. Patients with open bite malocclusions exhibit an obtuse gonial angle and high mandibular plane angle.

4. At the completion of active orthodontic treatment, most patients showed some amount of vertical incisor overlap. However, in only about one fourth of the patients had an incisal overlap of 2.5 mm or greater been achieved.

5. A comparison between untreated open and deep bite patients showed surprisingly similar skeletal and dental changes.

DEDICATION

To Lisa, Hannah, and my parents. Thank you for everything.

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TABLE OF CONTENTS

	PAGE
ABSTRACT	ii
DEDICATION	iv
ACKNOWLEDGEMENTS	v
LIST OF FIGURES	vii
LIST OF TABLES	viii
INTRODUCTION	1
REVIEW OF THE LITERATURE	3
STATEMENT OF THESIS	28
METHODS AND MATERIALS	30
RESULTS	39
DISCUSSION	48
SUMMARY AND CONCLUSIONS	69
APPENDIX	71
LITERATURE CITED	79

LIST OF FIGURES

FIGURE		PAGE
1.	Cephalometric Tracing With Linear and Angular Measurements	33
2.	Cephalometric Tracing With Linear and Angular Variables	34
3.	Bodily Verses Tipping Movements of Incisors for Open Bite Correction	36
4.	Relative Contributions of Variables for Open Bite Correction	49
5.	Mean Skeletal Changes	50
6.	Mean Dental Changes: Bodily Movements	53
7.	Mean Dental Changes: Tipping Movements	54
8.	Incisor Inclination and Positional Change	56
9.	Mean Angular Changes	58
10.	Mean Change in Overbite	60
11.	Methods of Open Bite Measurement	62

LIST OF TABLES

TABLE		PAGE
1.	Comparison Between the Control and the Treated Groups	39
2.	Comparison Between the Control and the Treated Groups at Time 1	40
3.	Comparison of the Changes from Time 1 to Time 2 for the Control and the Treated Groups	42
4.	Comparison of Treatment Changes (T1-T2) for Males and Females Within the Treated Group	44
5.	Comparison of Changes (C1-C2) for Males and Females Within the Control Group	45
6.	Describing Measurement Error	46
7.	Describing Tracing Error	47
8.	Comparison Between the Changes From Time 1 to Time 2 for the Control Groups in the Current Investigation and Parker's 1990 Study of Deep Bite Correction	67

INTRODUCTION

An anterior open bite is a malocclusion in which there is no vertical overlap of the maxillary and mandibular incisors when a patient is closed in maximum intercuspation. Nahoum (1975) divided his description of anterior open bites into two broad categories: patients with dental open bites in the absence of any craniofacial malformations and those patients with craniofacial dysplasias in addition to the dental open bites.

Nahoum described the cause of simple dental open bites to be an obstructed eruption of the anterior teeth caused by habits such as thumb sucking. The second group had characteristics common to several independent studies: increased lower anterior face height, obtuse gonial angle, and steep mandibular plane (Hapak 1963, Shudy 1964, Subtelney and Sakuda 1964, Sassouni and Nanda 1964, Richardson 1969) .

Although anterior vertical elastics are often used to extrude the incisors in an attempt to close open bite malocclusions, Subtelney and Sakuda (1964) found a supraeruption of upper incisors present in the average skeletal open bite patient. Since eruption of anterior teeth is often undesirable, treatment options often include attempts to close

the open bite by decreasing lower facial height through mandibular autorotation.

In the most severe cases, Sassouni and Nanda (1964) recommended the extraction of eight permanent teeth to accomplish bite closure: maxillary and mandibular first bicuspids, maxillary first molars, and mandibular second molars. A more common option (Isaacson 1971, Pearson 1978) for the treatment of the open bite patient includes four bicuspid extractions to aid in bite closure by allowing the molars to move forward and the incisors to upright.

The purpose of this investigation is to determine the relative contribution of various skeletal and dental components in the orthodontic correction of open bite malocclusions. The sample included thirty-one subjects treated with four first bicuspid extractions and fixed edgewise appliances. A cephalometric analysis (Parker 1990), which utilizes six linear measurements and two angular measurements, was utilized in evaluating the dental and skeletal changes that occurred during orthodontic treatment. The analysis isolates tipping from bodily movements of the upper and the lower incisors and assesses vertical skeletal changes in the maxilla and the mandible.

LITERATURE REVIEW

In a study which examines the treatment of open bite malocclusions, it seems pertinent to first ask what would be the outcome of no treatment at all. Worms et al., (1971) studied the prevalence of open bite malocclusions in a cross-sectional study of 1,048 Navajo children aged seven to twenty-one. Visual examinations were performed and results were plotted for various age groups. From his data, Worms found the prevalence of anterior open bite malocclusions to be 80% greater during the mixed dentition when compared to the prevalence during the permanent dentition. He speculated that this correction may be related to some "developmental factor" which is present in the mixed dentition period.

Parker (1971) speculated that this "factor" was related to tongue posture changes from the mixed to the permanent dentition. When the deciduous teeth are lost, Parker explained, the tongue expands laterally to form a seal while swallowing. For the patient with a tongue thrust habit, the tongue moves more posterior which allows the anterior teeth and alveolar process to erupt into a more normal position. In light of this possible self correction, the orthodontist should closely examine the use of interceptive treatment during this age period.

Clearly, the astute orthodontic practitioner recognizes both the difficulty and importance of providing treatment for the high angle skeletal open bite patient. Interestingly, individuals with no orthodontic training recognize the open bite profile as one which is esthetically displeasing. DeSmit and Dermaut (1984) investigated personal preference in soft-tissue profiles. They presented nine profile types proposed by Sassouni and Nanda (1964) and instructed people to rank them in order of personal preference. His results showed that Angle Class One (Cl I) normal profiles were the most appreciated; Cl I deep bite cases were also well-liked. It became difficult to distinguish preference differences between Angle Class Two (Cl II) and Angle Class Three (Cl III) normal and deep bite profiles. Most important for the present investigation was that open bite profiles were overwhelmingly most disliked. These results suggest that practitioners should avoid orthodontic intervention strategies that create long-face features.

Vertical Development

Hapak (1963) performed a cephalometric study which attempted to locate and describe the skeletal and dental differences found in open bite patients. He questioned whether open bite malocclusion was the result of disoriented growth or a manifestation of abnormal function. Hapak studied 52 untreated subjects with open bite malocclusions who ranged in age from ten to sixteen. Cephalometric radiographs were analyzed according

to Down's method. The sample exhibited a Cl II tendency. According to the Down's polygon, the Frankfort mandibular angle averaged 33.4 degrees. Finger and tongue habits produced wide variation from normal. The results also showed that when the Frankfort mandibular plane angle increased, the lower facial height, total facial height and alveolar height in the mandibular incisor area all increased significantly. Hapak proposed that growth compensation occurred in an attempt to preserve a balanced or reciprocal growth trend; when this compensation failed, a malocclusion resulted.

Shudy (1963) found the angle formed between the occlusal plane and the mandibular plane (OM angle) was an indicator of retrognathia and prognathia. He found that when the OM angle exceeded 23 degrees, there was a tendency towards a skeletal open bite malocclusion.

In 1964, Shudy introduced the terms "hyperdivergent" and "hypodivergent" to describe high angle cases with increased lower anterior facial height and low angle cases with decreased lower facial height.respectively. While the terms retrognathia and prognathia describe skeletal antero-posterior (AP) problems, the terms hyperdivergent and hypodivergent describe vertical variations. Shudy found that the hyperdivergent facial type could be characterized by a high mandibular plane angle, increased facial height, and increased OM angle.

Shudy (1965) studied the cephalometric radiographs of over four hundred patients, some orthodontically treated, some untreated for the purpose of documenting the growth changes which produced clockwise and counterclockwise rotations of the mandible. He described these rotations as an "in harmony" between vertical and antero-posterior growth. Clockwise rotation resulted from excessive vertical growth centered in the molar region rather than the condyles. In severe cases, the excessive vertical growth could cause open bite malocclusions. In addition to vertical problems, excessive vertical growth effected the antero-posterior position of the mandible causing it to drop downward and backward on rotation.

Subtelny and Sakuda (1964) compared the lateral cephalometric radiographs of twenty-five subjects with persistent open bites to thirty subjects with normal occlusion. In defining an open bite malocclusion, Subtelny and Sakuda felt that there had to be a definite separation between the upper and lower incisal edges relative to the occlusal plane. They statistically compared the dental-facial and skeletal relationships of open bite malocclusions to normal occlusions. The most significant differences were found in the size, shape and position of the mandible. The subjects with malocclusions generally showed mandibular retrognathia with an increased mandibular plane angle and a more obtuse gonial angle.

Sassouni and Nanda (1964) studied the vertical proportions of the face by examining longitudinal cephalometric records of eight persons with skeletal deep bites and eight persons with skeletal open bites. They identified three significant differences related to the mechanism of origin of skeletal open bites as compared to skeletal deep-bites: (1) the position of the condyles is higher in the open bite case, (2) the ramus is shorter in the open bite case, and (3) the maxillary molars are lower in the open bite. He felt these three factors were the fundamental differences responsible for the other "symptoms" of the skeletal open bite; i.e., increased lower facial height, high mandibular plane angle, and obtuse gonial angle.

Bjork (1969) examined methods for predicting mandibular growth rotation in a longitudinal cephalometric study of one hundred subjects with metallic implants in their jaws. Bjork described two types of extreme growth patterns which can result in a deep-overbite (forward rotation) or an open bite (backward rotation). He listed seven structural signs which could be used as a 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 of the mandible
4. a less prominent chin button
5. decreased interincisal angle

6. mesial inclination of molars and premolars
7. increased lower anterior face height.

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

Richardson (1969) examined lateral cephalometric radiographs of 110 untreated open bite and 110 deep-bite subjects in an attempt to identify differences in craniofacial morphology from these extremes in incisor overlap. In the introduction to his article, Richardson pointed out that the traditional Angle classification of malocclusion utilizes antero-posterior relationships of teeth and not vertical relationships, despite the fact that antero-posterior corrections are often limited by corrections in the vertical dimension. The study found the lower facial height and gonial angle to be significantly increased in open bite as compared to deep-overbite cases.

Gershater (1972) studied the causes, effects, and treatment of open bite malocclusion in a controlled environment. He studied children who suffered from emotional disturbances as well as

mental retardation. Gershater subjectively examined sixty-five children aged eight to fifteen. Of those examined, twenty-one (32.3%) had open bite deformities. In an effort to evaluate cause and effect, he discussed the idea that improper muscle control, present in this population, led to problems with the jaw, tongue, mouth, and swallowing pattern. He concluded that treatment in many of these cases was contraindicated due to etiologic and compliance problems.

Nahoum (1975) divided his description of anterior open bites into two broad categories: patients with simple dental open bites in the absence of any craniofacial malformations, and those with craniofacial dysplasias in addition to the dental open bites. Nahoum described the cause of simple dental open bites to be an obstructed eruption of the anterior teeth precipitated by habits such as thumb sucking. The second group had many open bite characteristics described in previous studies: increased lower anterior face height, obtuse gonial angle, and steep mandibular plane (Hapak 1963, Shudy 1964, Subtelny and Sakuda 1964, Sassouni and Nanda 1964, Richardson 1969) .

In an editorial publication, Watson (1981) cited many factors that may contribute to open bite malocclusion. In an attempt to make a differential diagnosis, he felt all hereditary and environmental factors were important to consider. Factors to consider include growth discrepancy, dental equilibrium, genetic factors, external and environmental influences. Included are jaw

posture, eruptive forces and occlusal forces. Lastly, postural position, tongue thrusting and various oral habits must be considered.

When assessing vertical skeletal relationships in a patient, Proffit (1986) felt the first step was a measurement of anterior facial height. While many analyses yield an absolute measurement of facial height, the proportion of upper facial height; i.e., nasion to anterior nasal spine (ANS), to lower anterior facial height; i.e., ANS to menton, is the most important. In a balanced face, the lower facial height should be 55% of the total anterior facial height. A second indicator of vertical development used by Proffit is the relative convergence or parallelism of the mandibular plane, occlusal plane, and palatal plane. In the high angle open bite patient, these planes will rapidly converge to a point just behind the face .

Nanda (1990) studied growth patterns in subjects with long and short faces. He performed cephalometric tracings on thirty-two subjects noting particular landmarks and planes. Nanda demonstrated a statistical correlation between cranial base angles and gender. He found no correlation between angles and facial dysplasias. The open bite cases exhibited a progressive reduction in angles which reduced or maintained the open bite with age. By contrast, deep bite cases consistently showed an increase in overbite. This change was attributed to the reduction in Frankfort Mandibular Angle (FMA) and Gonial Angle (Go) with

age. Nanda was unable to define a specific predictor of growth. He found dentoalveolar growth to be the same in both open and deep bite cases. This was surprising because the malocclusions had very different final outcomes.

Functional Considerations

Speidel et al., (1972) reviewed tongue-thrust therapy and its relationship to anterior dental open bite. Contrary to previous belief, he questioned the existence of a causal relationship between the two. Although he stated that abnormal morphology promoted abnormal muscle activity and therefore, tongue thrusting enhanced an open bite tendency. he concluded that tongue-thrusting was not the primary cause of anterior open bite malocclusions.

Lowe (1980) performed cephalometric and electromyographic analysis on twenty-four individuals. Specifically, he studied genioglossus, masseter and oblicularis oris activity as it related to craniofacial morphology. Lowe observed that low threshold values of genioglossus and masseter activity related to negative overbite, undererupted incisors, and increased lower face height. The correlation between genioglossus threshold values and negative incisor overbite suggested that tongue posture may effect incisor eruption. Lack of eruption, in turn, lead to an open bite malocclusion. He found no relationship between open bites and oblicularis oris function.

His research demonstrated a definite relationship between muscle development and eruption of the dentition.

Bresolin et al., (1983) studied mouth breathing in allergic children. They evaluated whether this type of breathing was related to facial growth. Bresolin et al., examined forty-five Caucasian children between the of ages six and twelve. They summarized that the mouth-breathers were more retrognathic than the control group, they had an increased lower face height, and they had a higher mandibular plane angle. The mandible exhibited a more obtuse gonial angle and the palate was deeper and more narrow. Mouth-breathers were also more likely to have cross-bites.

Trask et al., (1987) compared the developmental characteristics of mouth-breathing in children with allergic rhinitis to their unaffected siblings. Examining twenty-five pairs of children, Trask focused on the relationship between nasal obstruction and facial growth. They found that nasally obstructed children expressed a more divergent facial pattern with an increase in lower anterior facial height. They concluded that nasal obstruction affected growth in the vertical plane while genetic factors controlled antero-posterior relationships.

Overbite Correction

There are several different opinions as to the correct amount of vertical overlap of the upper and the lower incisors. These opinions range from specific millimeter measurements, to

percentage measurements, to anatomical relationships. Neff (1949) reported the "ideal" incisor relationship as having 20% of the lower incisor covered by the upper incisor when the teeth were in maximum intercuspation. Williamson (1976) stated that the ideal incisor overlap was accomplished when the incisal edge of the lower incisor rested on the cingulum of the upper central incisor. Ricketts (1982) found the mean values for overbite and overjet to be 2.5 mm in his studies of ideal dental and skeletal relationships.

Treatment Options

Although anterior vertical elastics are often used to extrude incisors in an attempt to close open bite malocclusions, Subtelney and Sakuda (1964) found that there was already a supraeruption of upper incisors in the average skeletal open bite patient. While vertical elastics can further elongate already supraerupted incisors, this could explain the high incidence of relapse in open bite cases (Lopez-Gavito et al., 1985). Their study suggested that molar depression, rather than incisor elongation, might produce more favorable results in open bite closure.

Sassouni and Nanda (1964) recognized that all forces which tend to extrude molars (intermaxillary elastics, cervical headgear, etc.) should be avoided in treating the Cl II open bite case. His treatment strategy involved rotating the mandible in a closing direction and lowering the premaxilla. In the most severe

cases, Sassouni recommended the extraction of eight permanent teeth to accomplish bite closure: maxillary and mandibular first bicuspids, maxillary first molars, and mandibular second molars

Kuhn (1968) felt that posterior tooth eruption was the most important influence on the anterior vertical control of the lower face. He described various mandibular positions as an expression of molar eruption and depression. A one millimeter vertical change in the molar region resulted in approximately three millimeters of mandibular rotation measured at gnathion. He discussed the force vectors and moments delivered by various methods of extraoral anchorage to maintain control of anterior vertical dimension.

Parker (1971) examined the effectiveness of interceptive treatment of the open bite malocclusion during the early growth period. He presented case reports on seven various types of open bite malocclusions in children 5.5 to 13 years of age. Treatment involved two bands placed on the upper incisors with soldered wire extensions directed downward and backward. The wires extended one millimeter below the incisal edge of mandibular central incisors. The sharp prongs reminded the patients to keep their tongues and thumbs from between the incisors. Although Parker showed favorable results, Worms et al., (1971) concluded that 80% of these simple open bites will undergo spontaneous correction during this time period with no treatment at all.

When treating a high angle open bite patient, Isaacson et al., (1971) felt it was important to band only the necessary teeth, preferably not the second molars. The Curve of Spee should not be leveled because this will make the open bite even worse. Isaacson also recommended the avoidance of intermaxillary elastics to avoid bite opening. He suggested that bicuspid extractions aid in bite closure by both allowing the molars to come forward and the incisors to upright.

Pearson (1973) recognized the importance of posterior molar eruption in vertical control. He discussed the use of mandibular posterior intrusive forces for treating moderately steep mandibular plane angle patients. He found that while significant lower posterior height increases can occur during extraction therapy, mandibular headgears and sliding jigs can be effective in delivering intrusive forces to the lower posterior teeth. While the control group showed three millimeters of mandibular molar height increase over 2.5 years, the mandibular headgear and sliding jig groups a showed 1.5 mm increase.

With all of the treatment options available, Nahoum (1975) still felt that the orthodontic practitioner should consider surgery to be the "primary method" of treating skeletal open bite malocclusions.

Bell et al., (1977) described the technical aspects of surgically repositioning the jaws to correct a skeletal open bite with vertical maxillary excess and an increased lower face

height. They felt the surgical approach was often indicated because it was doubtful if orthodontics alone could decrease maxillary posterior height enough to achieve facial balance and an attractive smile. Orthodontic bite closure often involves tipping of the maxillary and mandibular incisors around their apices. This type of treatment can result in excessive incisor exposure and an increase in the gingival tissue displayed during a smile.

With the surgical approach, the relationship of the upper lip line to the maxillary incisors is the "keystone" to surgical treatment planning. Bell et al., described the surgical technique for a typical skeletal open bite patient which involved a LeFort I Osteotomy with a genioplasty. The maxilla is impacted to reduce facial height, close the open bite through mandibular autorotation, reduce incisor tooth exposure, and establish lip competency at rest. More chin prominence can then be gained with a genioplasty if needed.

Pearson (1978) discussed methods of vertical control in patients with backward-rotational growth tendencies. For the growing patient, Pearson recommended removal of the four first bicuspids just after eruption. While waiting for the eruption of the remaining teeth, a vertical chin cup is worn by the patient a minimum of twelve hours per day. In a sample of twenty patients, this treatment closed the anterior open bites in all patients prior to fixed appliances and decreased the mandibular plane angle an average four degrees.

Pearson recommended a high pull headgear and lingual arch to the maxillary first molars as another treatment alternative during the mixed dentition. When the maxillary molars are out of occlusion two to three millimeters, the removal of the remaining deciduous teeth allows the mandible to hinge forward to close the open bite.

Haas (1980) discussed a "biological approach" to the treatment of skeletal and dental open bite malocclusions. In the non-growing adult, Haas concentrates treatment mechanics towards posterior tooth intrusion to close a skeletal open bite. In the growing skeletal open bite patient, there are three areas of focus:

1. inhibition of posterior tooth eruption
2. prevention of normal maxillary descent
3. redirection of mandibular growth into a more horizontal direction

Haas recommended the use of a vertical-pull chin cup to accomplish all three of these goals.

Frankel and Frankel (1983) described a "functional" approach to treating a skeletal open bite malocclusion by using his own design of removable appliance called a "functional regulator". They compared a series of lateral cephalometric radiographs of thirty patients treated with a functional regulator to eleven untreated skeletal open bite cases. The treated group showed a significant decrease in mandibular plane angle, gonial

angle, and lower facial height. They showed a closure of the open bite and an increase of ramus length in the treated group.

Since there is often a supraeruption of the maxillary molars associated with open bite malocclusion, Dale (1985) suggested the possibility of first permanent molar extraction in place of bicuspid extraction. By removing the posterior stop, the mandible can rotate upward and forward to help close the anterior open bite. One drawback to this technique is lack of predictability of third molar eruption at an age which is prior to second molar eruption.

Garrington and Logan (1989) studied cephalometric radiographs of twenty three Angle Class II, Division I (Cl II, Div I)cases. They focused on the enucleation of mandibular second premolars and theorized that this procedure may prove beneficial for vertical control in high mandibular plane angle cases. Their findings supported his theory. They showed that by enucleating these teeth, the first bicuspids are able to drift distally; by creating additional space anteriorly, few incisor or canine rotations occur. Mesial drift of mandibular first molars decreased posterior alveolar height and aided in creating a significant decrease in lower face height.

Galletto et al., (1990) showed favorable results in treating an adult anterior open bite by focusing the primary objective of treatment towards molar intrusion. A maxillary bite block which exceeded freeway space was used to intrude mandibular molars.

Following the maxillary bite block, a mandibular bite block in conjunction with posterior high pull headgear was used for the intrusion of maxillary molars. By intruding maxillary (two millimeters) and mandibular (1.5 mm) molars the open bite was eliminated through mandibular autorotation.

Chabre (1990) recommended the use of a combination headgear-activator to maintain vertical control while treating a Cl II Div I malocclusion with an anterior open bite. By bending the outer bow of the headgear downwards, the force application passes behind the skeletal and dental centers of resistance in the maxilla. Pre and post treatment superimpositions showed a clockwise rotation of the palatal plane and anterior mandibular rotation, resulting in favorable hard and soft tissue changes.

Pearson (1991) published a case report in which he accomplished favorable results in treating a severe open bite patient non-surgically. By using a vertical pull chin cup throughout treatment, Pearson was able to control vertical growth and close the open bite without extruding the anterior teeth.

Relapse

Lopez-Gavito et al., (1985) evaluated treatment response based on post-retention analysis of previously treated open bite patients. The forty-one subjects had been out of retention a minimum of nine years, six months and were evaluated using computer analysis of pretreatment, postreatment and long-term

cephalometric tracings and dental casts. Although more than 35% exhibited post-retention relapse of three millimeters or more, the authors were unable to define a reliable predictor of either postreatment relapse or stability.

Huang et al., (1989) studied the stability of open bite cases treated with crib therapy. The original data was collected on thirty-three patients; this group was subdivided into growing and non-growing individuals. Of twenty-three growing patients, four exhibited relapse. Relapse did not occur in any of the non-growing group. The authors stated that patients who exhibited a favorable overbite following crib therapy were likely to remain that way after orthodontic treatment was completed.

Intrusion Magnets

With the introduction of magnets to orthodontics (Blechman and Smiley 1978) came a new method of force application for producing tooth movements. Blechman (1985) descried how posterior repelling magnets could be used to intrude molars in open bite cases. This application presented the possibility of bite closure through mandibular autorotation in a manner similar to posterior extractions, but without the loss of dental units.

Dellinger (1985) introduced a removable magnetic appliance called the "active vertical corrector" which provided a non-surgical treatment alternative for the skeletal open bite patient. The appliance contained repelling samarium cobalt magnets which were incorporated into maxillary and mandibular bite blocks.

Three case histories were presented which showed dramatic bite closure after four to seven months of treatment. Cephalometric superimpositions showed that bite closure was the result of molar intrusion and mandibular autorotation. Dellinger recommended that the patients wear the appliance for a minimum of twelve hours per day.

Kalra et al., (1989) examined the effects of a similar magnetic intrusion appliance in a broader study of ten patients with Cl II Div I malocclusions and increased lower facial height. Unlike Dellinger's appliance, this appliance was not removable but rather fixed to the upper and lower arches to provide uninterrupted force application.

During the four month treatment period, the treatment group showed 1.6 mm of upper and lower molar intrusion while the control group showed 0.4 mm of eruption. In addition to molar intrusion, Kalra noted a statistically significant increase in mandibular length when compared to the control group.

One side effect of the appliance was the creation of temporary buccal crossbites after appliance removal. As the repelling magnets were moved together, lateral forces were generated which caused the patients' mandibles to deviate to one side.

Barbre and Sinclair (1991) performed a cephalometric evaluation of twenty-five open bite patients treated with the "active vertical corrector" (Dellinger 1985). During an 8 month

treatment period, the appliances were cemented to the upper and lower arches to ensure full-time wear. On average, there was three millimeters of anterior open bite correction during the treatment period. The authors conclude that bite closure was largely due to maxillary and mandibular molar intrusion, followed by mandibular rotation and bite closure.

The data reflects 0.5 mm of maxillary and mandibular molar intrusion for the treatment group, while the control group showed 0.5 mm of molar eruption. There was, however, only a one degree decrease in the mandibular plane.

History of Magnets in Orthodontics

The use of magnets in dentistry has been documented for nearly forty years. Their use was first documented in the literature in 1953 as an aid in denture retention (Behrman and Egan 1953) The prosthodontic profession recognized the need for improved retention in a certain number of their edentulous patients.. In this brief research report, the use of magnets were described as implanted retention aids of the lower jaw.

In 1978 the use of magnets as an orthodontic force first appeared in the literature (Blechman and Smiley 1978). Two small AlNiCo magnets were attached separately to the maxillary teeth of young cats. One was bonded in the molar region, and the other to the cuspid. The magnets were oriented so they had an attracting force to retract the cuspid. The nine month study

suggested the biologic safety of the magnets and provided a precise an efficient force mechanism for tooth movement.

During the mid 1970's, the introduction of small yet very powerful samarium-cobalt magnets made the use of magnets in dentistry much more feasible. In 1984, a method of diastema closure using magnets appeared in the European literature (Muller 1984). In the limited study of seven patients, maxillary diastemas were successfully closed by bonding small samarium-cobalt magnets to the labial surface of the central incisors. The author found no adverse effects to the oral tissues, and saw mainly bodily movement of the teeth with minimal tipping in this friction-free setup. The study suggested that more complicated tooth movements could be achieved by further utilizing magnets in orthodontics.

Blechman (1985) published the results of a pilot study in which small SmCo magnets were used for intermaxillary and intramaxillary mechanics to orthodontically move teeth. In addition to presenting two case which demonstrated the efficacy of magnetic force systems, Blechman diagramed how the magnets could be setup both with attracting and repelling forces to accomplish a variety of desired tooth movements. The diagrams showed how attracting forces could be utilized for cuspid retraction and Cl II mechanism. Blechman also described the use of posterior repelling magnets to intrude molars in open bite cases.

In his two case presentations, Blechman was able to provide intermaxillary forces without the need for elastics or patient cooperation. Both patients reported no discomfort during treatment.

Sandler (1989) described another orthodontic application of magnets in an article which showed magnets used to aid the eruption of an impacted canine. The tooth was exposed and a small neodynium-iron-boron magnet was bonded to the labial surface. Another magnet was placed on a removable appliance to guide the tooth into place. After four months, the tooth was well positioned enough to allow final positioning with fixed appliances.

Since the first orthodontic tooth movements using magnets were described by Blechman and Smiley (1978) there have been a wide variety of clinical applications of magnets in orthodontics which include diastema closure, molar distalization, posterior intrusion, palatal expansion, and facilitated eruption of impacted teeth.

Animal Studies

A posterior high-pull headgear is often recommended to maintain vertical control when treating a high angle skeletal open bite malocclusion. Meldrum (1975) examined the effects in upper facial growth in growing Macaca monkeys resulting from a high-pull headgear. The monkeys had a full deciduous dentition and erupted first permanent molars. A high-pull headgear that

exerted three hundred grams per side was worn full time for the eighty to ninety day experimental period. When evaluating cephalometric changes, Meldrum found that this method of force application was capable of slowing, stopping, or even reversing the normal downward and forward maxillary development.

Bite blocks which open the posterior vertical dimension are often used to control posterior eruption in high angle open bite causes. McNamara (1977) examined the dentoalveolar and craniofacial changes resulting from increased vertical dimension in growing Macaca monkeys. Bite blocks which opened the vertical dimension from two to fifteen millimeters were worn full time during the twelve to twenty week experimental period.

Even with minimal bite opening, there was a decrease in the normal downward and forward development of the maxilla. Despite these maxillary changes, even fifteen millimeters of bite opening showed no intrusion of the lower buccal segments.

Brandt et al., (1979) performed a similar study, but this time used adult Macaca monkeys. A high-pull headgear exerting 450 grams per side was worn full time for the 84 to 205 day experimental period. Brandt et al., was testing the hypothesis that it should be possible to effect the spatial location of the maxillary complex in adult patients. The adult monkeys were used as a model to test this hypothesis. While there was a slower rate of skeletal movement in the adult monkeys, there

were substantial changes in the maxillary complex both vertically and antero-posteriorly.

Altuna and Woodside (1985) tested the effects of different vertical openings using posterior bite blocks in juvenile Macaca monkeys. The vertical dimension was opened two, eight, and twelve millimeters. The animals with the thickest bite blocks had the greatest skeletal and dentoalveolar changes. The maxilla was displaced in an upward and forward direction, rather than the normal downward and forward development in the control groups. All experimental animals showed inhibited eruption or intrusion of the maxillary permanent molars.

Woods and Nanda (1988) used growing baboons to test the effectiveness of magnets to intrude posterior teeth. The study used appliances similar to those used by Dellinger (1986) and Kalra et al., (1989) which incorporated repelling magnets into bite blocks. The control group used bite blocks without magnets. While the study showed rather dramatic intrusion of posterior teeth in the growing baboon, they found no significant difference between the control and the experimental groups. The authors caution the reader about extrapolating the data to human patients since the baboon's growth patterns are far different from that of human growth patterns.

Vardimon et al., (1989,1990) has published several studies which have examined the skeletal and dental changes which occur in monkeys wearing various magnetic appliances. Two studies in

particular showed encouraging results for the correction of skeletal Cl II and skeletal Cl III malocclusions in a relatively short period of time.

Safety

Up until the mid 1970's, there were few studies published which examined the effects magnetic fields had on mammalian tissue. The studies showed magnetic field to be biologically harmless (Toto 1962). Later studies showed that extremely large magnetic fields did have some harmful effects on mammalian tissues including delayed healing (Gross and Smith 1964).

Studies by Cerney (1978) examined the reaction of dental tissues to magnetic fields. These studies were more practical for the field of dentistry, since they studied magnetic fields which were smaller and more similar to the forces used in dentistry. His conclusions were that the samarium-cobalt magnets produces no apparent harmful biological effects on mammalian tissues.

STATEMENT OF THESIS

The purpose of this investigation was to determine the relative contribution of various skeletal and dental components in open bite correction. Thirty-one patients were selected from the finished cases in the Orthodontic Department at Case Western Reserve University. The cases were selected on the basis of zero vertical incisor overlap and no incisor contact at the start of treatment. In addition, all patients had adequate initial and deband radiographs. All patients were treated with four first bicuspid extractions and fixed edgewise appliances. The treated group was matched by age, sex and treatment time with a sample of untreated open bite patients from the Bolton Collection, Cleveland, Ohio.

By using a matched sample, one can factor out normal growth changes by subtracting the mean changes in the Control Group from the mean changes in the Treated Group. This allows the investigator to separate those changes occurring as the result of orthodontic treatment alone.

A cephalometric analysis (Parker 1990) which utilized six linear measurements and two angular measurements was used 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 from bodily movements of the upper and the lower incisors and assessed vertical skeletal changes in the maxilla and the mandible.

METHODS AND MATERIALS

Group Set-Up

A sample consisting of thirty-one subjects treated for open bite malocclusions were selected from the completed files of the Department of Orthodontics at Case Western Reserve University. All subjects were treated with the extraction of four first bicuspid and fixed edgewise appliances. These thirty-one subjects were selected strictly from an evaluation of pre-treatment radiographs to avoid outcome bias in subject selection.

The thirty-one treated open bite subjects were matched by sex, age, and treatment time interval to thirty-one untreated open bite subjects from the Bolton Study, Cleveland, Ohio (see Table 1). For the purpose of the present study, a criterion of 0% incisor overlap (or less as viewed from the occlusal plane) and no incisor contact was used as the definition of an open-bite malocclusion.

Cephalometric Analysis

Once selected, 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 the statistical comparisons, a cephalometric analysis was utilized which contains six linear and two angular measurements (Parker 1990) (see Fig. 1). The linear measurements were made to the nearest 0.1 mm using a Fowler

"Max-Cal" electronic digital caliper. All angular measurements were made to the nearest 0.5 degree using a Ricketts "dome" orthodontic template.

A cephalometric analysis (Parker 1990) was used to evaluated dental and skeletal changes from time one to time two for both the Treated (T1-T2) and the Control Groups (C1-C2). All measurements were made from a constructed horizontal reference line which connected Pt point and a point 3 millimeters above Orbitale (Kishiyama 1987). To compare pre and post treatment radiographs, the lateral cephalometric radiographs were superimposed using the sphenoethmodial junction and anterior cranial base as stable landmarks. Regional superimpositions on the maxilla and the mandible were utilized to discriminate between skeletal rotations and dental tipping when evaluating treatment effects.

The following linear measurements were made perpendicular from the constructed horizontal reference line (see Fig. 1):

Measurement one: (M1)	The distance from the horizontal reference line to anterior nasal spine (ANS).
Measurement two: (M2)	The distance from the horizontal reference line to the center of resistance of the maxillary incisor.

Measurement three: (M3) The distance from the horizontal reference line to the incisal edge of the maxillary incisor.

Measurement four: (M4) The distance from the reference line to the incisal edge of the mandibular incisor.

Measurement five: (M5) The distance from the reference line to the center of resistance of the mandibular incisor.

Measurement six: (M6) The distance from the horizontal reference line to Menton (Me).

These six linear measurements produce seven variables which were used to assess anterior vertical changes. These variables are described as follows (see Fig. 2):

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

2. Bodily movement of the maxillary incisor (BUI) was evaluated by subtracting M1 from M2.

3. Tipping movements of the maxillary incisor (TUI) was evaluated by subtracting M2 from M3.

4. Bodily movement of the mandibular incisor (BLI) was evaluated by subtracting M5 from M6.

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

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

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

Cephalometric Tracing With Linear And Angular Measurements

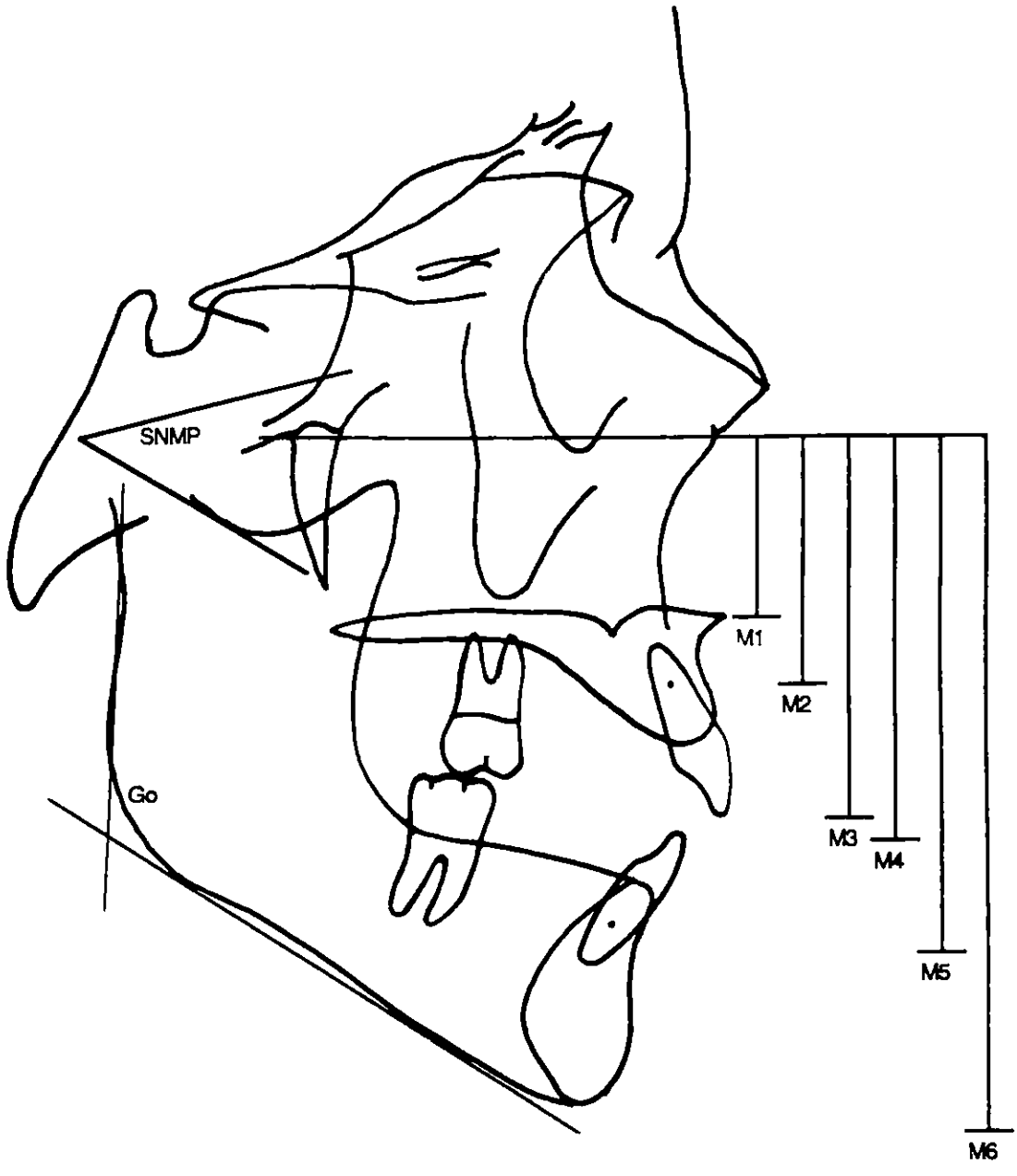


Figure 1. Cephalometric tracing showing the six linear and two angular measurements used in the vertical analysis

Cephalometric Tracing With Linear And Angular Variables

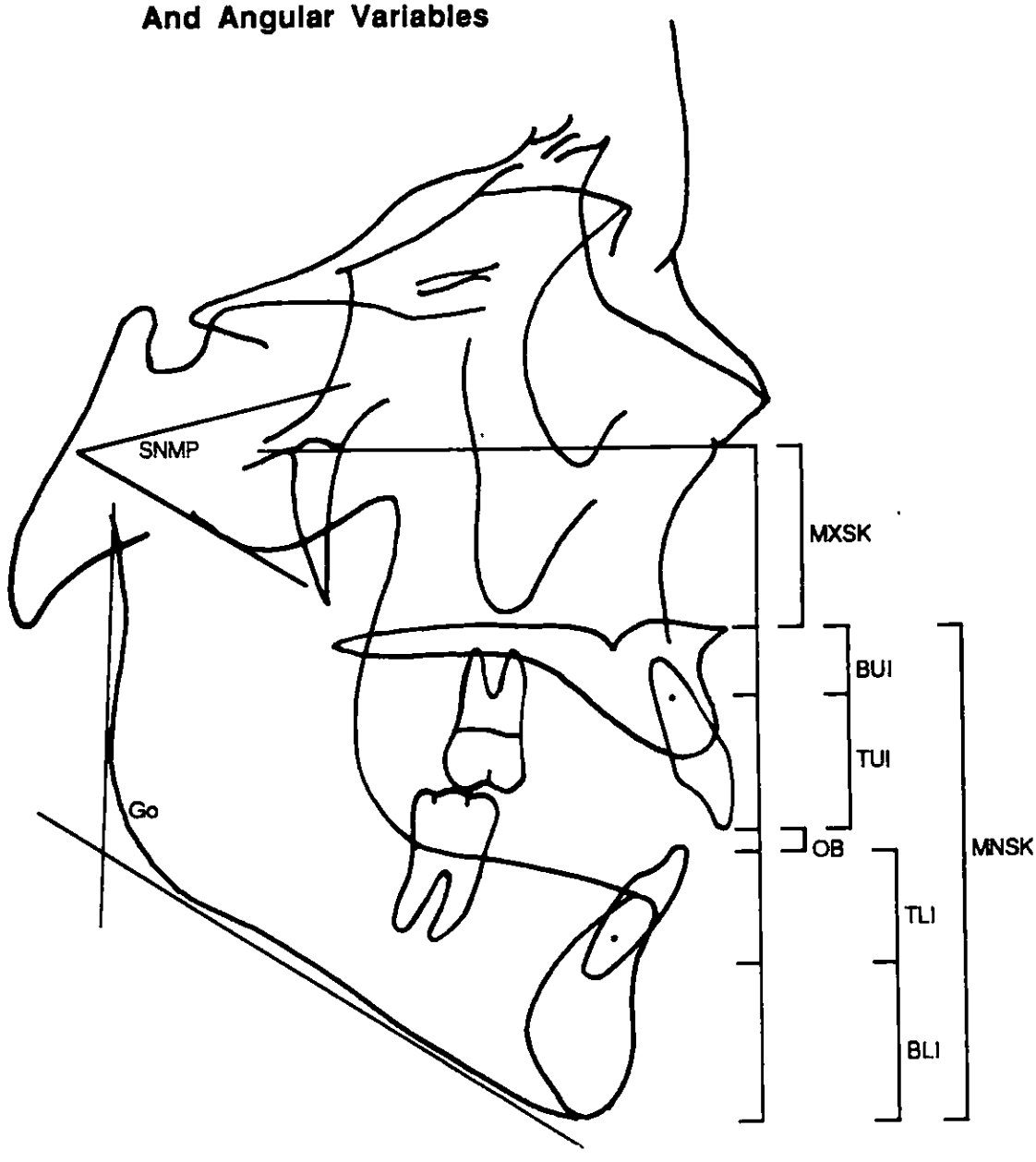


Figure 2. Cephalometric tracing showing the seven linear and two angular measurements used in the vertical analysis: MXSK = M1, BUI = M2 - M1, TUI = M3 - M2, TLI = M5 - M4, BLI = M6 - M5, MNSK = M6 - M1, OB = M3 - M4, GO, SNMP

Angular changes of the gonial and mandibular plane angles were also made in the present investigation.

Convention of Signs

All dental and skeletal changes which help to vertically increase incisor overlap were given a positive sign; those which decrease overlap were given a negative sign. Stated differently, all dental and skeletal movements which were in a direction towards the occlusal plane were given a positive sign, while all movements away from the occlusal plane were given a negative sign.

+ MXSK: downward movement of ANS relative to cranial base
- MXSK: upward movement of ANS relative to cranial base

+ BUI: extrusion of the upper incisor relative to ANS
- BUI: intrusion of the upper incisor relative to ANS

+ TUI: lingual tipping of the upper incisor
- TUI: labial tipping of the upper incisor

+ TLI: lingual tipping of the lower incisor
- TLI: labial tipping of the lower incisor

+ BLI: extrusion of the lower incisor relative to menton
- BLI: intrusion of the lower incisor relative to menton

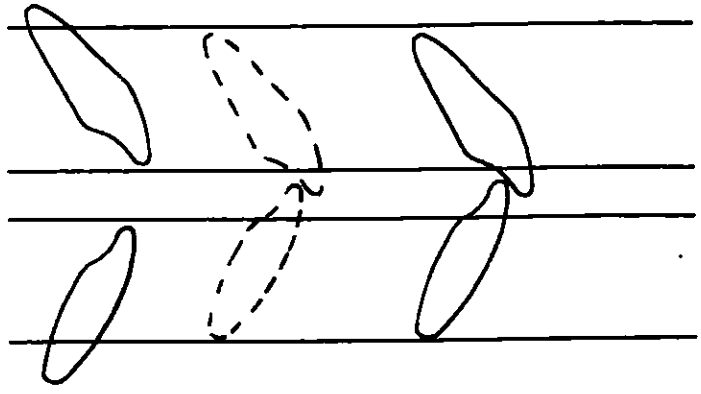
+ MNSK: upward movement of menton relative to ANS
- MNSK: downward movement of menton relative to ANS

+ Go: Gonial angle becomes more acute
- Go: Gonial angle becomes more obtuse

+ MPA: Mandibular plane became more closed
- MPA: Mandibular plane became more open

Bodily Verses Tipping Movements

PURE BODILY MOVEMENT



PURE TIPPING MOVEMENT

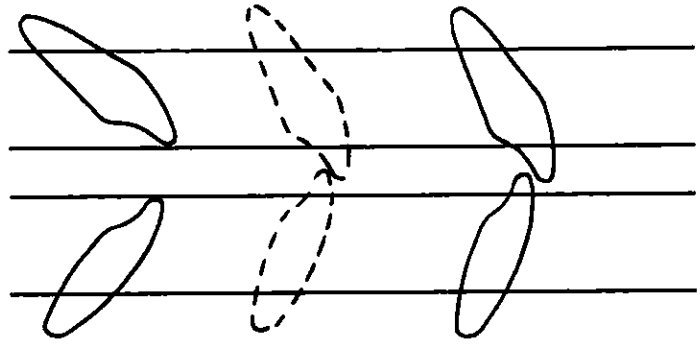


Figure 3. Comparing bodily movements verses tipping movements of the upper and the lower incisors for open bite correction.

Statistics

The purpose of this investigation was to determine the relative contributions of various skeletal and dental components in open bite correction. By using a matched sample, one can factor out normal growth changes by subtracting the mean changes in the Control Group from the mean changes in the Treated Group. This allows the investigator to separate those changes occurring as the result of orthodontic treatment alone.

All data was analyzed in the Orthodontic Department at Case Western Reserve University utilizing the SPSS/PC statistical program. For each of the seven linear measurements and two angular measurements examined in the present study, the mean, standard deviation, and standard error measurement was calculated for both the Treated Group (T1-T2) and the Control Group (C1-C2). The mean changes were then tested for statistical significance by utilizing paired t-tests.

Error Assessment

To evaluate the degree of investigator measurement error, ten 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 were then compared to the first set using reliability coefficients.

Tracing error was evaluated in a similar manner. Ten radiographs were retraced by the investigator and the

cephalometric analysis repeated on those tracings. The calculations for the seven linear and two angular measurements were compared for the first and the second set of tracings utilizing reliability coefficients.

RESULTS

Patient Sample Description

Both the Control and the Treated Groups contained a total of thirty-one individuals who exhibited an open bite malocclusion as evident on the initial lateral cephalometric radiograph. Each group contained a total of eighteen female and thirteen male subjects (see Table 1). The Mean age of the Control Group at Time 1 was 12.8 years, while the Treated Group was 13.0 years. The average time interval between initial and final radiographs for the Control and Treated groups was forty and forty-one months respectively.

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

	CONTROL	TREATED
TOTAL SAMPLE	31	31
# of FEMALES	18	18
# of MALES	13	13
AGE: TIME 1	12y 10m	13y 0m
AGE: TIME 2	16y 2m	16y 5m
TIME 1 TO TIME 2	40 months	41 months

Control Verses Treated Group at Time 1

Although both the Treated and the Control Groups were carefully matched for age, sex, and time interval, there were three variables that were significantly different ($p < 0.01$) when comparing the initial radiographs of both groups (see Table 2). The mean values for BUI and BLI were greater in the Treated Group than the Control Group; both the upper incisors (2.7 mm) and the lower incisors (2.1 mm) were positioned more occlusally in reference to ANS and Menton within the Treated Group.

TABLE 2.--Comparison Between the Control and Treated groups at Time 1

	CONTROL		TREATED			
VARIABLE	MEAN	SEM	MEAN	SEM	P-VALUE	SIG.
MXSK	24.5	0.65	24.9	0.61	0.643	
BUI	9.6	0.45	12.3	0.68	0.002	* *
TUI	17.1	0.18	16.6	0.25	0.15	
TLI	13.5	0.25	13.2	0.21	0.372	
BLI	23.7	0.45	25.8	0.55	0.006	* *
MNSK	64.5	0.79	68.4	1.01	0.003	* *
OB	-0.7	0.15	-0.6	0.26	0.823	
GO	129.5	1.01	130.6	1.32	0.513	
MPA	39.6	0.98	40.8	0.84	0.343	

* significant $p < 0.05$, ** sig. $p < 0.01$, *** sig. $p < 0.001$

The Variable MNSK was also significantly ($p<0.01$) greater in the Treated Group than the Control Group. At the start, the Treated Group was 3.9 mm longer in the lower facial height than was the Control Group.

Initially, there were no significant differences ($p<0.05$) between the groups in the amount of open bite, the axial inclination of the upper and the lower incisors, the position of the maxilla, the mandibular plane angle, or the gonial angle.

The Control Group

The Control Group showed 0.6 mm of bite closure during the 40 months between initial and final radiographs (see Table 3). The mean values for variables MXSK, BUI, TLI, BLI, GO, and MPA all moved in a positive direction for anterior open bite closure. The mean values for the variables TUI and MNSK had a negative effect on open bite closure.

The Treated Group

The Treated Group showed 2.3 mm of bite closure during the 41 months between initial and final radiographs (see Table 3). The mean values for the variables MXSK, BUI, TUI, TLI, BLI, and Go all moved in a positive direction for anterior open bite closure. The mean values for the variables MNSK and MPA had a negative effect on open bite closure.

Control Verses Treated Group From Time 1 to Time 2

The upper and the lower incisors showed a highly significant ($p< 0.001$) amount of lingual tipping (TUI and TLI) to

TABLE 3.--Comparison of the Changes from Time 1 to Time 2 for the Control and Treated groups

	CONTROL		TREATED			
VARIABLE	MEAN	SEM	MEAN	SEM	P-VALUE	SIG.
MXSK	2.4	0.38	2.8	0.37	0.571	
BUI	1.1	0.18	1.1	0.37	0.873	
TUI	-0.2	0.17	1.8	0.29	0.000	***
TLI	0.3	0.12	1.1	0.21	0.001	***
BLI	2.1	0.37	2.2	0.45	0.806	
MNSK	-2.7	0.53	-3.9	0.56	0.000	***
OB	0.6	0.24	2.3	0.37	0.000	***
GO	1.6	0.31	2.1	0.38	0.287	
MPA	0.8	0.27	-0.3	0.51	0.028	*

* significant $p< 0.05$, ** sig. $p< 0.01$, *** sig. $p< 0.001$

facilitate open bite closure. The combination of the variables TUI (1.8 mm) and TLI (1.1 mm) accounted for 2.8 mm more anterior open bite closure through incisor tipping in the Treated Group when compared to the Control Group.

Mandibular skeletal height (MNSK) increased significantly (3.9 mm, $p<0.001$) in the Treated Group. This vertical change was in a negative direction in terms of open bite correction.

Along with the mandibular skeletal height, the mandibular plane in the Treated Group opened slightly (0.3 degrees) which had a negative effect on open bite correction. This was statistically

different ($p < 0.05$) from the Control Group which had a 0.8 degree closure of the mandibular plane.

When comparing the overall changes between the Control and the Treated Groups (see Table 3), there was no significant difference between the mean values for the variables MXSK, BUI, BLI, and Go. The extraction of four first bicuspids followed by forty-one months of orthodontic treatment had no significant effect on the vertical position of the maxilla, the bodily movement of the upper and the lower incisors relative to the maxilla and the mandible, or the gonial angle.

Changes Within the Control Group by Sex

Within the Control Group, males showed a significantly greater increase ($p < 0.05$) in both the maxillary skeletal height (MXSK) and the mandibular skeletal height (MNSK) when compared to the females (see Table 5). The males also showed a significantly greater amount of bodily extrusion of both the upper and the lower incisors.

There was no significant difference between males and females within the Control Group for the variables TUI, TLI, OB, Go, and MPA.

Changes Within the Treated Group by Sex

As with the Control Group, the males in the Treated Group showed a significantly ($p < 0.001$) greater amount of mandibular skeletal change than the females (see Table 4). Along with the

mandibular changes, the males showed a significantly ($p < 0.001$) greater amount of bodily extrusion of the lower incisors (BLI).

There was no significant difference between males and females within the Treated Group for the variables MXSK, BUI, TUI, TLI, OB, Go, and MPA.

TABLE 4.--Comparison of treatment changes (T1-T2) for Males and Females within the Treated Group

	MALE		FEMALE			
VARIABLE	MEAN	SEM	MEAN	SEM	P-VALUE	SIG.
MXSK	3.6	0.73	2.2	0.32	0.105	
BUI	1.2	0.56	1.0	0.50	0.836	
TUI	1.7	0.43	1.8	0.41	0.815	
TLI	1.2	0.33	1.1	0.27	0.808	
BLI	3.9	0.70	1.0	0.37	0.001	***
MNSK	-6.3	0.74	-2.1	0.50	0.000	***
OB	1.6	0.42	2.7	0.54	0.114	
GO	2.2	0.70	2.1	0.42	0.932	
MPA	0.7	0.93	-1.0	0.52	0.120	

* significant $p < 0.05$, ** sig. $p < 0.01$, *** sig. $p < 0.001$

TABLE 5.--Comparison of changes (C1-C2) for Males and Females within the Control Group

	MALE		FEMALE			
VARIABLE	MEAN	SEM	MEAN	SEM	P-VALUE	SIG.
MXSK	3.6	0.75	1.6	0.25	0.024	*
BUI	1.6	0.24	0.8	0.22	0.024	*
TUI	-0.4	0.37	-0.1	0.14	0.344	
TLI	0.2	0.15	0.4	0.18	0.279	
BLI	3.4	0.32	1.1	0.31	0.005	* *
MNSK	-4.7	0.81	-1.3	0.50	0.002	* *
OB	0.0	0.37	1.0	0.30	0.058	
GO	1.5	0.63	1.6	0.29	0.981	
MPA	1.1	0.38	0.7	0.37	0.449	

* significant p< 0.05, ** sig. p< 0.01, *** sig. p< 0.001

Measurement Error

Ten radiographs were randomly selected to assess the amount of investigator error associated with measuring the six linear measurement using a digital caliper and the two angular measurements using a protractor. The ten radiographs were measured for a second time, and the two sets of means compared for each variable using reliability coefficients (see Table 6). All linear measurements were made to the nearest 0.1 mm and the angular measurements to the nearest 0.5 degrees. The

measurement error was very small, with all reliability coefficients between 96% to 99%.

TABLE 6.--Describing Measurement Error

	MEASUREMENT 1		MEASUREMENT 2		
VARIABLE	MEAN	STD	MEAN	STD	RCOEF
MXSK	2.6	1.98	2.6	2.03	.9976
BUI	1.2	2.81	1.2	2.72	.9987
TUI	2.1	1.99	2.1	2.00	.9989
TLI	1.0	1.48	1.1	1.44	.9965
BLI	2.3	2.61	2.3	2.56	.9982
MNSK	3.6	3.00	3.6	2.95	.9988
OB	3.0	2.34	3.1	2.41	.9988
GO	2.7	2.54	2.6	2.77	.9912
MPA	-0.2	0.98	-0.2	1.11	.9604

Tracing Error

In addition to measurement error, investigator tracing error was assessed by retracing ten randomly selected radiographs. The ten radiographs were traced and measured for a second time, and the two sets of means compared for each variable using reliability coefficients (see Table 7). The tracing error was very small, with the reliability coefficients for the means of all variables between 95% to 99%.

TABLE 7.--Describing Tracing Error

	TRACING 1		TRACING 2		
VARIABLE	MEAN	STD	MEAN	STD	RCOEF
MXSK	2.6	2.03	2.9	1.88	.9871
BUI	1.2	2.71	1.1	2.31	.9890
TUI	2.1	2.00	1.9	1.95	.9927
TLI	1.1	1.44	1.0	1.27	.9516
BLI	2.3	2.56	2.5	2.21	.9879
MNSK	3.6	2.95	3.4	2.89	.9920
OB	3.1	2.41	3.0	2.44	.9888
GO	2.6	2.76	2.3	2.57	.9801
MPA	-0.2	1.11	0.1	1.10	.9672

DISCUSSION

The purpose of this investigation was to determine the relative contributions of various skeletal and dental components in open bite correction. It was demonstrated that the majority of open bite correction in these thirty-one extraction cases came from lingual tipping of the upper (TUI) and the lower (TLI) incisors (see Figure 4). A 3.9 mm vertical increase in the Mandibular Skeletal Height (MNSK) had a significant ($p < 0.001$) negative effect on open bite correction.

An in-depth analysis of the relative contribution of each variable to open bite correction follows.

Skeletal Changes

There was no significant difference between the Control and the Treated groups when comparing the mean changes for the variable Maxillary Skeletal Change (MXSK). The Mandibular skeletal changes (MNSK), however, were significant at $p < 0.001$ (see Figure 5).

In addition to normal growth and development, there are other factors which effect the variable MNSK in the vertical analysis used in the present study. These factors include both vertical and anterior-posterior position of the maxillary and

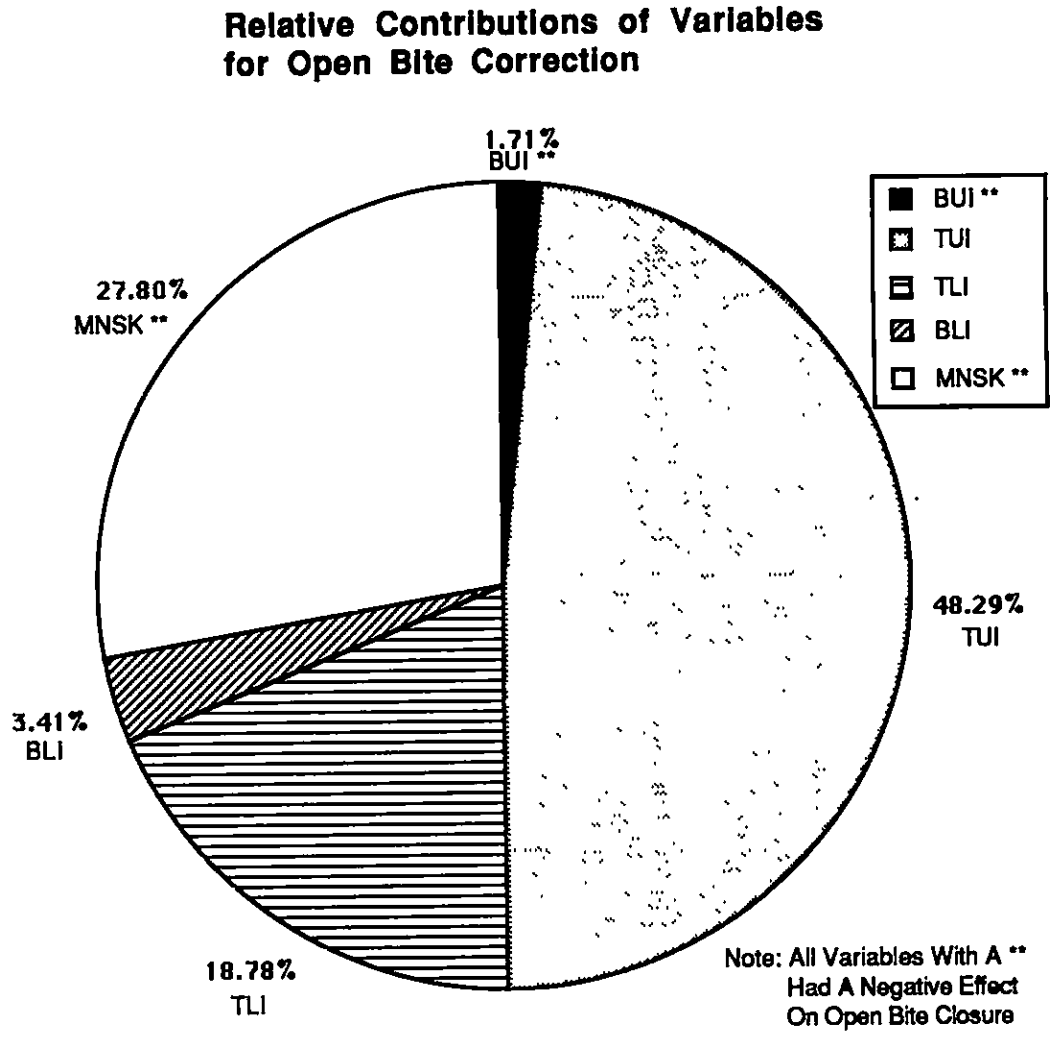


Figure 4. Contributions to open bite correction. The majority of correction came from lingual tipping of the incisors.Vertical mandibular changes had a substantial negative effect.

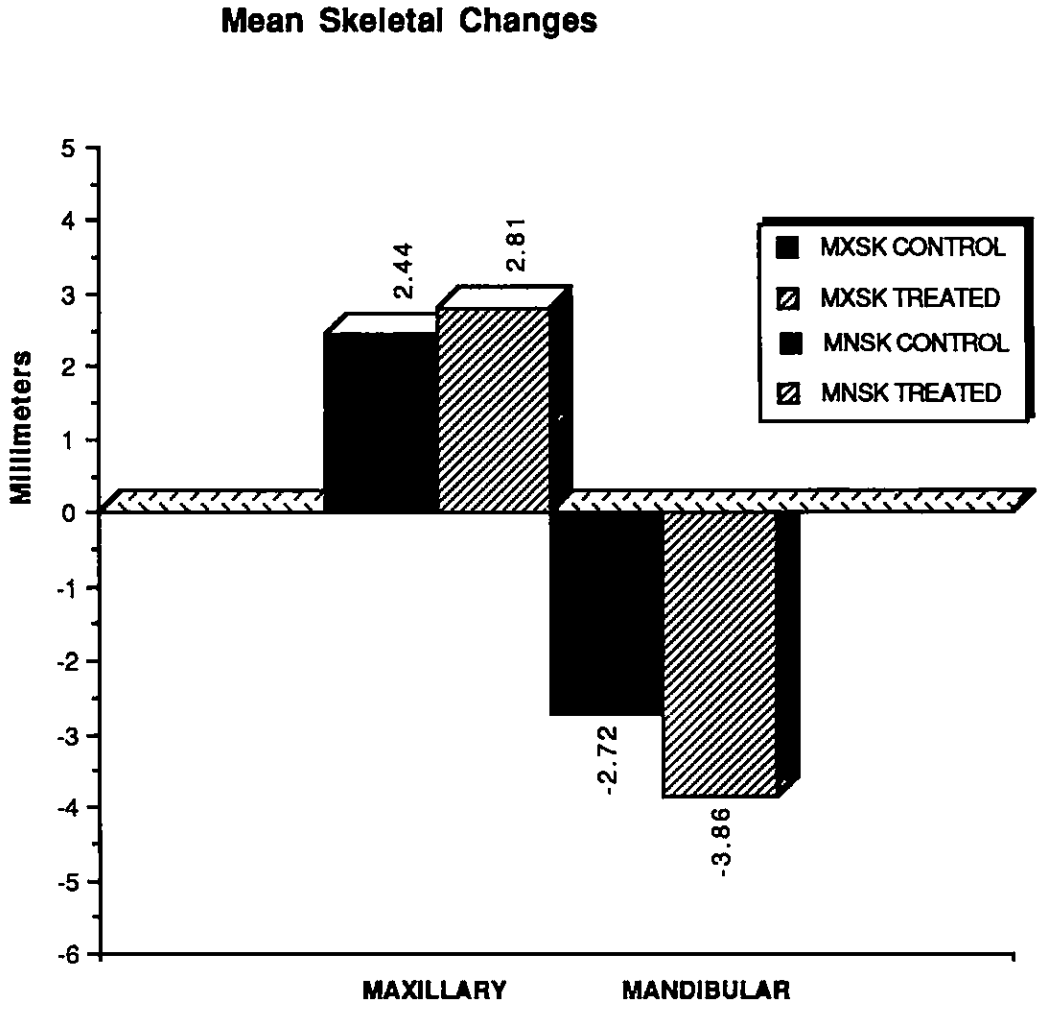


Figure 5. Mean changes for the maxilla and the mandible. The variable MNSK showed a significant increase in the Treated Group

mandibular molars, the gonial angle, and the vertical development of the maxilla.

Any extrusion of the posterior segments would have a negative effect on bite closure by increasing the vertical position of the mandible. Any mesial movement of the buccal segments would have a positive effect on bite closure by moving the wedge more anterior allowing for mandibular autorotation and bite closure.

Since some anchorage loss is present in space closure following premolar extractions (Isaacson et al., 1971, Pearson 1978), one must assume some mesial movement of the buccal segments in the Treated Group. As previously mentioned, this movement would have a positive effect on bite closure. However, despite the extractions there was still a statistically significant increase in lower facial height ($p < 0.001$) and slight opening (0.3 degrees) of the mandibular plane.

With no difference in the vertical position of the maxilla, and a decrease in the gonial angle, one can interpret the mandibular skeletal increase to be the result of vertical changes in the buccal segments. While the analysis used in the present study does not directly look at molar position, one can infer that there was some extrusion of maxillary and/or mandibular molars during the course of orthodontic treatment.

When examining the treatment mechanics used in the Treated Group, it would not be surprising to see some extrusion

of the buccal segments during treatment. The Treated Group could be roughly divided with about half of the subjects being treated with Tweed mechanics, and the other half with sliding mechanics. Both techniques rely heavily on intermaxillary elastics for Cl II correction, which have an extrusive component on the buccal segments.

One can speculate that we might have seen more effective bite closure in the Treated Group by extracting second bicuspids rather than first bicuspids. The extraction of second bicuspids would allow for more mesial movement of the buccal segments to facilitate bite closure. This more posterior extraction sequence, however, would not allow for as much lingual tipping of the incisors, which accounted for the majority of open bite correction.

It should be noted from the initial radiographs, that the Treated Group showed a significantly larger mandibular skeletal height (see Table 2). The variable MNSK was approximately 4 mm, or 6% larger at the start of treatment. Despite being 6% larger at the start, there was 30% more mandibular skeletal change in the Treated Group than the Control Group.

Dental Changes

The vertical analysis used in the present study enabled the investigator to separate bodily movements of the upper and the lower incisors from tipping movements (see Figures 3, 6, and 7). There was virtually no difference in the amount of incisor bodily

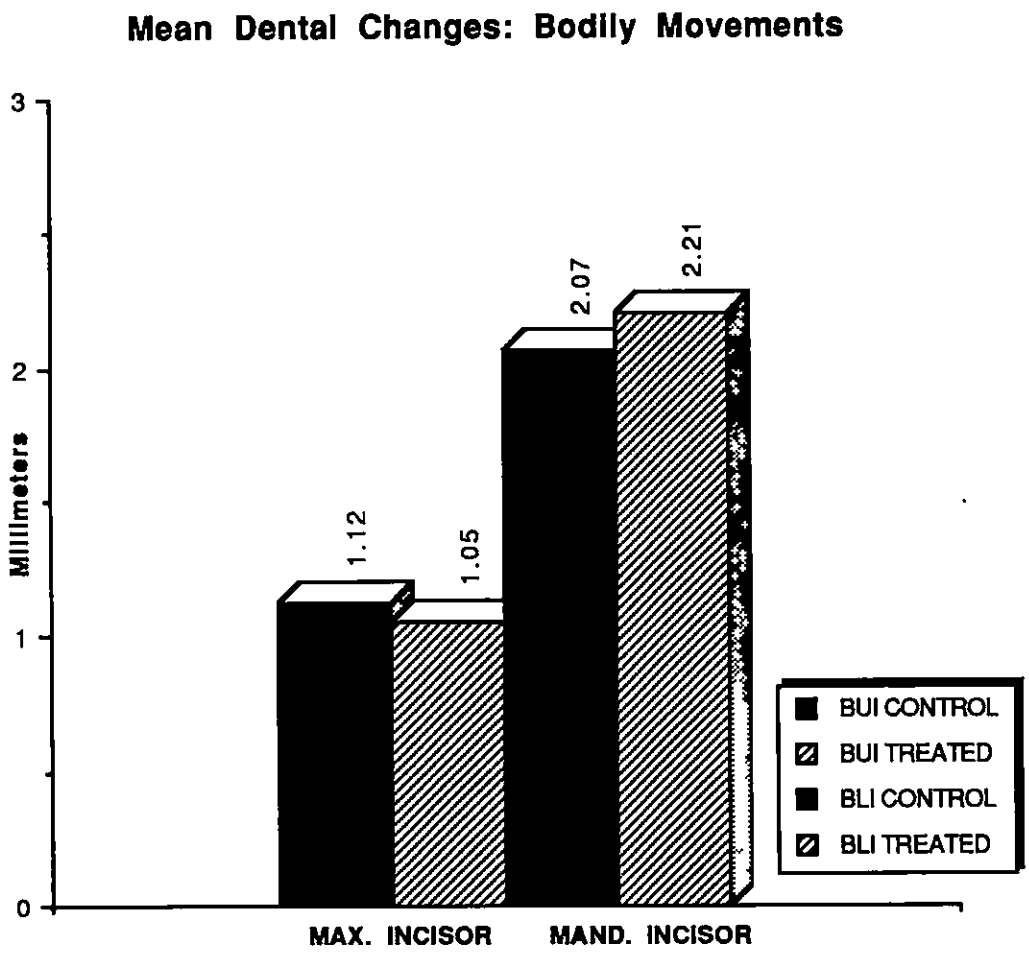


Figure 6. Bodily movements of the incisors. There was no significant difference between the Treated and Control Groups

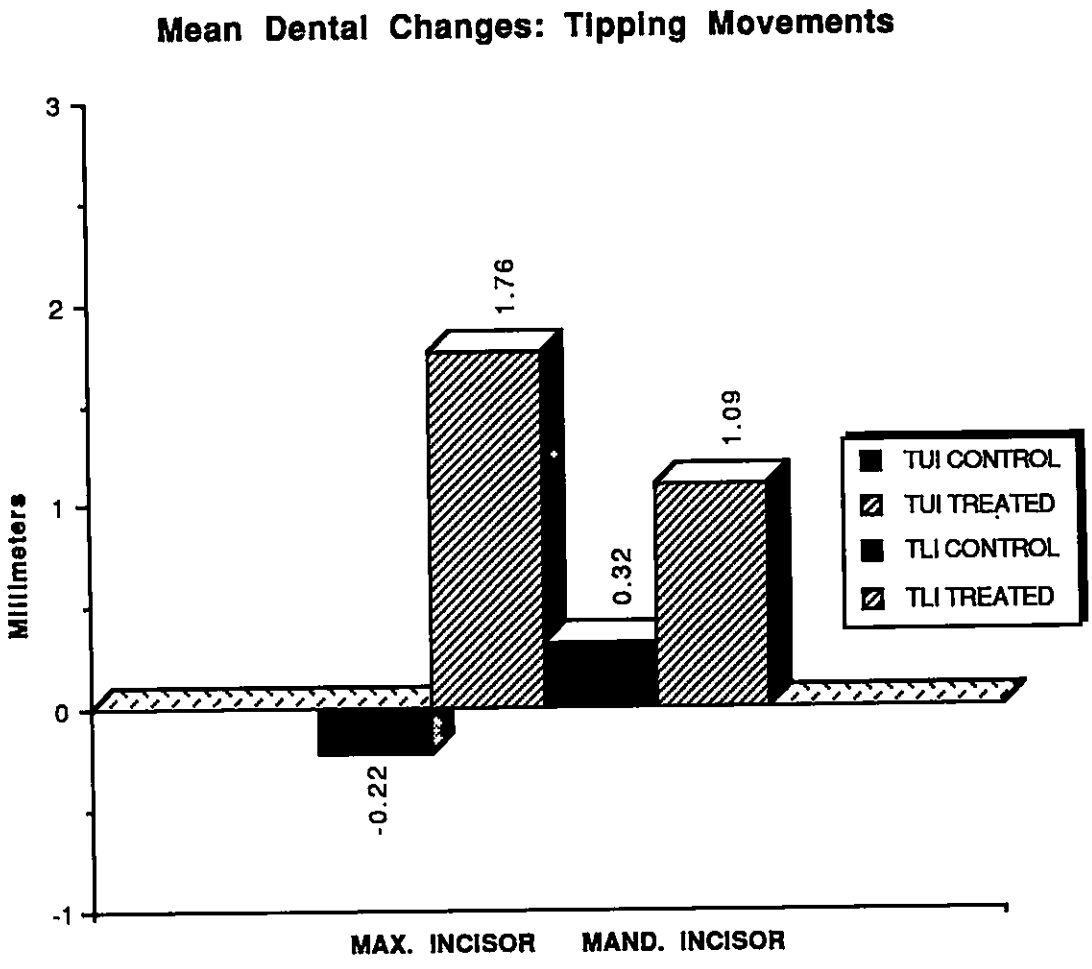


Figure 7. Tipping of the incisors. The Treated Group showed significantly more lingual tipping of the upper and the lower incisors.

extrusion (BUI and BLI) between the Control and the Treated groups.

The present study showed significantly ($p < 0.001$) more lingual tipping of the upper and the lower incisors in the Treated group as compared to the Control group (see Figure 7). This tipping accounted for 2.9 mm of open bite correction in the Treated Group as compared to 0.1 mm correction in the Control Group.

It is clear that the extraction of dental units provides space into which the incisors can be moved. In the absence of anterior spacing, the lack of extractions would not allow for lingual tipping of the anterior teeth to aid in open bite closure.

A second consideration which determines the effective lingual tipping of teeth for open bite correction involves the axial inclination of the upper and the lower incisors (see Figure 8). As an incisor tips lingually, there is both a horizontal and a vertical component to the movement. Highly proclined incisors allow for more open bite correction by lingual tipping than do incisors which are already upright. As an extremely proclined incisor moves by tipping from a horizontal position to a vertical one, the vertical component gradually becomes smaller as the horizontal component becomes larger. As this movement goes beyond the vertical position (as in a upright incisor), further lingual tipping would actually have a negative effect on open bite correction.

Incisor Inclination and Positional Changes

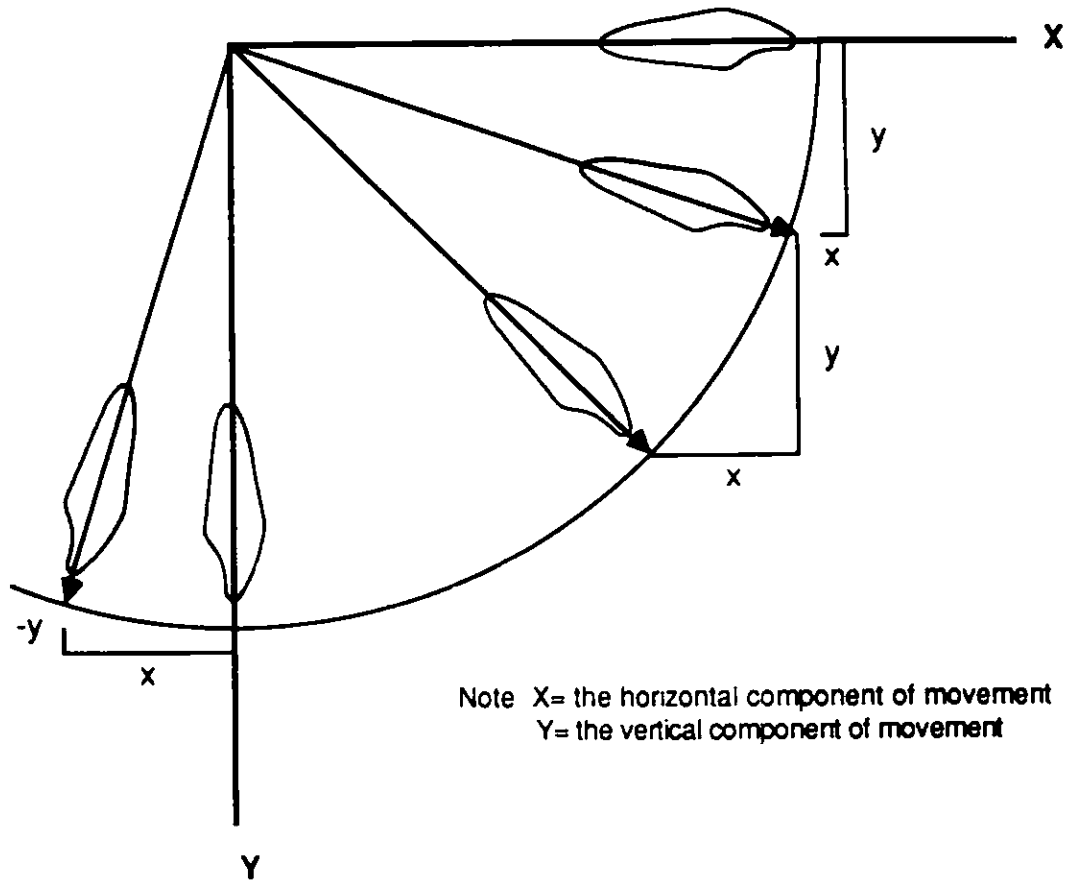


Figure 8. As the central incisor moves by tipping from a horizontal position to a vertical one, the vertical component becomes smaller as the horizontal component becomes larger As this movement goes beyond the vertical line, further lingual tipping would actually have a negative effect on open bite correction

Angular Changes

The normal cephalometric value for gonial angle is 123 degrees, plus or minus five degrees (Bell, 1980). From the initial radiographs, there was no significant difference ($p > 0.50$) in the measurement for gonial angle (Go) between the Control (129.5 degrees) and the Treated Groups (130.6 degrees). These measurements for gonial angle are consistent with previous studies which showed an increased gonial angle (129 degrees) in patients with open bite malocclusions (Subteleny 1964). Both the Control and Treated Groups showed a closing of the gonial angle with time (see Figure 8).

For the purpose of the present study, the measurement Sella-Nasion/ Mandibular Plane (SNMP) was used for the mandibular plane angle. It was selected over the Frankfort Horizontal/ Mandibular Plane (FH-MP) because of the greater accuracy in locating Sella-Nasion as compared to the Frankfort Horizontal Plane. On average, SNMP is seven degrees greater than the FH-MP measurement (Proffit, 1986).

From the initial radiographs, there was no significant difference in the measurement for SN-Mandibular Plane between the Control (39.6 degrees) and the Treated Groups (40.8 degrees). These measurements for the mandibular plane are consistent with previous studies which showed an increased mandibular plane (40.4 degrees) in patients with open bite malocclusions (Hapak 1964).

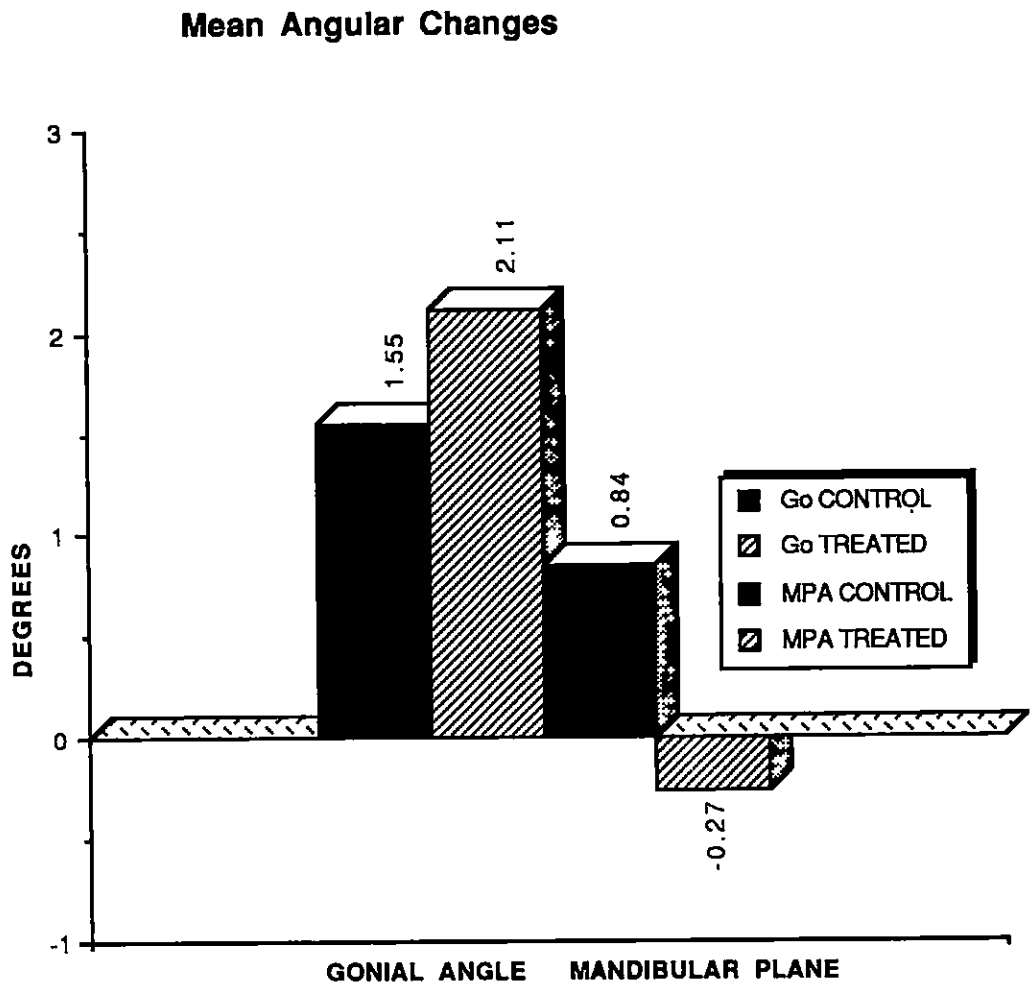


Figure 9. Mean changes for the Gonial and Mandibular Plane Angles. The Treated Group showed a significant opening of the Mandibular Plane.

There are several different definitions of what constitutes 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 degrees in a "high angle" case. This can be translated into a SNMP of 35 degrees. Clearly, the average subject in the present study, with a mean SNMP of 40 degrees, could certainly be considered a "high angle" open bite patient at the start of treatment.

With normal growth and development in an adolescent patient, one would expect the mandibular plane angle to decrease about one degree every three to four years (McNamara ,1986). This is consistent with the mean 0.8 degree decrease seen in the Control Group during the forty month interval. The Treated Group, however, showed a slight increase ($p < 0.05$) or opening of the mandibular plane during nearly the same interval (see Figure 9). This opening of the mandibular plane along with the increased MNSK had a negative effect on open bite closure.

Overbite Correction

When treating a patient with an open bite malocclusion, generally the orthodontist attempts to finish the case with more vertical incisor overlap than in a patient who started treatment with excessive incisor overlap. Since the results of the present study were represented as millimeter measurements, Ricketts (1982) ideal value of 2.5 millimeter was used as minimum value as basis for comparison.

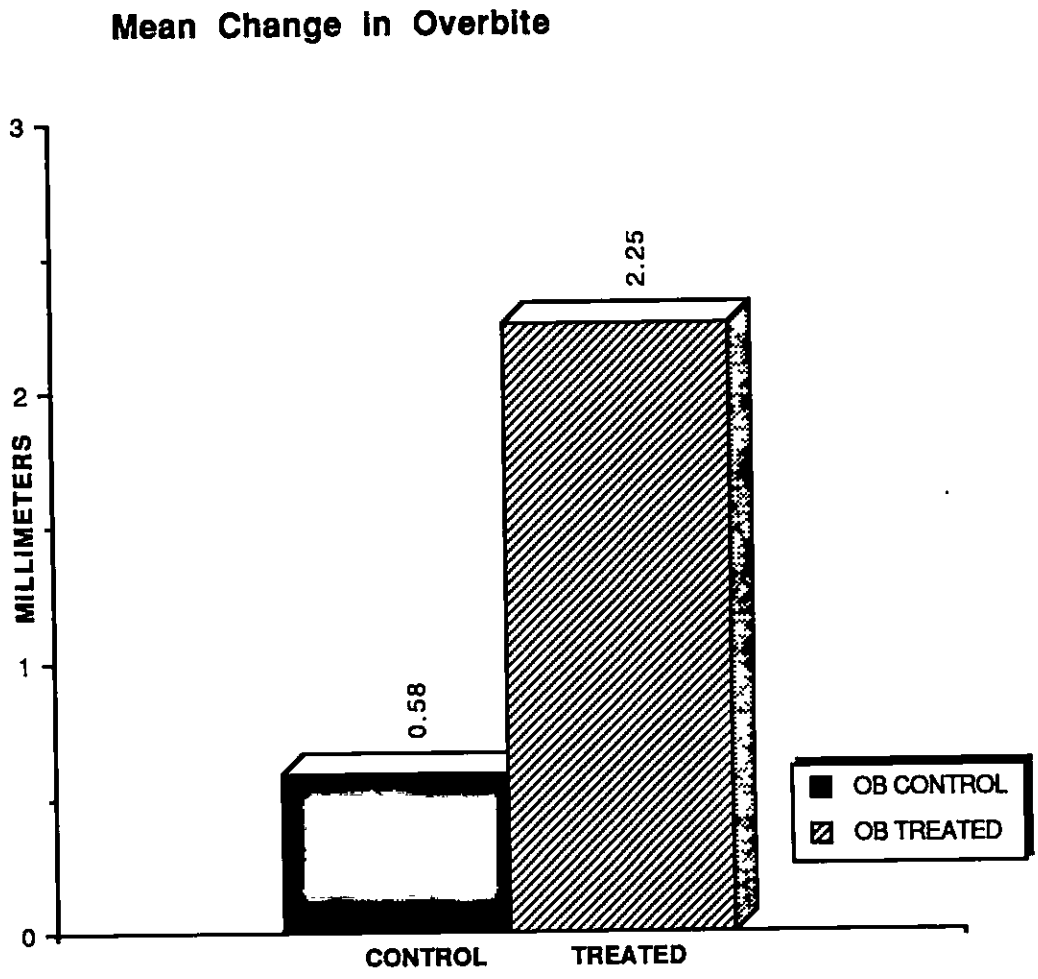


Figure 10. Overbite correction. The Treated Group had a significantly greater increase in vertical incisor overlap than the Control Group

At the completion of full orthodontic treatment, 87% of the patients in the Treated group (27 of 31) had some amount of vertical incisor overlap. However, only 23% of the Treated Group (7 of 31) had an incisal overlap of 2.5 millimeters or greater. In the Control group, no patients showed this amount of overbite.

While one could say the orthodontic treatment was successful (87%) in closing the open bite malocclusions, few cases exhibited an ideal incisor relationship at the end of treatment.

It was noted that in the vertical analysis used in the present study, there was a tendency to slightly over-estimate the amount of vertical incisor overlap (OB), making the open bite malocclusions seem less severe than they really were. 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 millimeters) which approximates the Frankfort Horizontal plane. In a normal dentofacial relationship, the horizontal plane and the occlusal planes will diverge anteriorly 11 degrees, plus or minus three degrees (Graber, 1985).

With these two lines diverging, as the antero-posterior distance between the upper and the lower incisors increases, so does the difference between the clinical measurement open bite and the measurement used in the present investigation. The difference between these two measurements is illustrated in

Methods of Open Bite Measurements

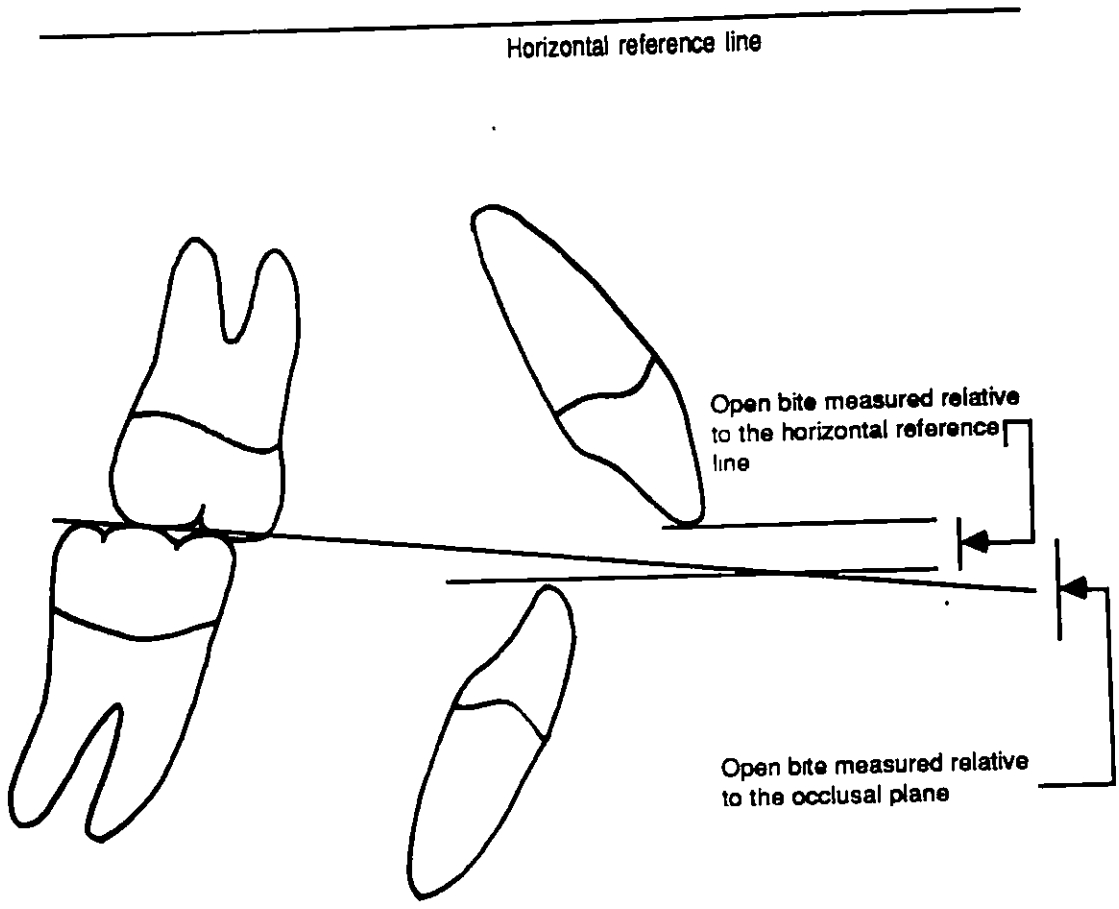


Figure 11. By measuring relative to the horizontal reference line, the measurement for an open bite malocclusion appears to be less severe than the actual clinical measurement.

Figure 11 which demonstrates a severe Angle Class II open bite malocclusion. Similarly, if there had been any Angle Class III malocclusions in the present investigation, the vertical analysis would tend to slightly over-estimate the measurement for vertical incisor overlap (OB), if the lower incisors were anterior to the upper incisors.

Comparison Between Males and Females

The average age of the sample at the start of treatment was almost thirteen years. 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. As expected, males within the Control Group showed a significantly greater increase in both the maxillary skeletal height (MXSK) and the mandibular skeletal height (MNSK) (see Table 5).

As with the Control Group, the males in the Treated Group showed a greater amount of maxillary (MXSK) and mandibular (MNSK) skeletal change than the female patients (see Table 4). Only the mandibular skeletal changes, however, were significantly different ($p < 0.001$) .

It is interesting that the only other significant difference between males and females in both groups was found in the bodily incisor movement associated with the statistically significant skeletal changes. The males in the Control Group showed a significantly greater ($p < 0.05$ and $p < 0.01$) amount of bodily

extrusion of both the upper (BUI) and the lower (BLI) incisors. This went along with the significantly greater ($p < 0.05$ and $p < 0.01$) increase in both the maxillary (MXSK) and mandibular (MNSK) skeletal height within the Control Group.

The male patients in the Treated Group showed a significantly greater ($p < 0.001$) amount of bodily extrusion of the lower incisors (BLI) only. This went along with the significantly greater ($p < 0.001$) increase in the mandibular (MNSK) skeletal height within the Treated Group.

One could interpret these bodily incisor movements as an internal mechanism of dental compensation for growth. As the maxilla and the mandible had a greater vertical increase for males during this time period, the incisors also moved vertically to compensate for the change. If this did not occur, then there would have been a significant difference in the amount of overbite (OB) change between the males and the females in both groups.

Comparison Between the Samples

For the purpose of the present investigation, the Control and the Treated Groups were matched on three criterion: Sex, Age, and Time interval (see Table 1). Each group was composed of thirty-one patient records; eighteen female and thirteen male. The mean ages at the time of initial radiographs for the two groups were within two months of the same age; at the time of the final radiographs they varied by less than three months. With

a relatively low incidence of open bite malocclusions in children in the United States (between 1% and 10% , Proffit, 1986), the sample in the present study represented a well matched group for investigation.

Although both the Treated and the Control Groups were carefully matched, there were three variables that were significantly different ($p < 0.01$) when comparing the initial radiographs of both groups (see Table 2). These variables were the bodily position of the upper (BUI) and the lower (BLI) incisors, and the variable for mandibular skeletal height (MNSK).

The mean values for both BUI and BLI were greater in the Treated than the Control group; both the upper and the lower incisors were positioned approximately 2 to 3 millimeters more occlusally in reference to ANS and menton within the Treated Group. Despite these differences, both groups showed nearly identical amounts of bodily movements during the study.

The variable MNSK was approximately 4 millimeters, or 6% larger at the start of treatment. Despite being 6% larger at the start, there was 30% more mandibular skeletal change in the Treated Group than the Control Group. The other skeletal measurement, maxillary skeletal height (MXSK), was also initially slightly larger in the Treated Group but this was not statistically significant.

Although the mean age of the Treated was slightly older (2 months) at the start of treatment, this in itself can not entirely

explain difference between the groups for these three variables. It is interesting that as the maxilla and the mandible had a slightly greater vertical measurement for the Treated Group, the incisors also moved vertically (BUI and BLI) to compensate for the change. This allowed for a nearly identical relationship of the upper and the lower incisors at the start in terms of their protrusion (TUI and TLI) and their negative incisor overlap (OB).

Previous Studies

A comparison was made between the mean changes for the the Control Group in the current investigation and the Control Group in Parker's 1990 study of deep bite correction (see Table 8). Both studies utilized the same vertical analysis, and had similar time intervals between initial and final radiographs (forty and thirty-eight months). The two studies contained vastly different samples: the present study consisted of high angle open bite patients while the other included low angle deep bite patients. Despite these differences, the two groups were surprisingly similar in their skeletal and dental changes.

The variables MXSK, BUI, TLI, BLI, OB, GO, and MPA all moved in the same direction and had a similar magnitude of change. Overbite (OB) increased slightly in both groups as the upper (BUI) and the lower (BLI) incisors exhibited bodily movement towards the occlusal plane and the lower incisors (TLI) tipped lingually. Both groups showed similar decreases in both the gonial angle (Go) and the Mandibular Plane angle (MPA).

TABLE 8.--Comparison between the changes from Time 1 to Time 2 for the Control Groups in the current investigation and Parker's 1990 study of deep bite correction

	DIETRICH 1992	PARKER 1990	
VARIABLE	CONTROL MEAN VALUES	CONTROL MEAN VALUES	DIFFERENCE
MXSK	2.4	2.5	0.1
BUI	1.1	1.2	0.1
TUI	-0.2	0.3	0.5
TLI	0.3	0.2	0.1
BLI	2.1	2.6	0.5
MNSK	-2.7	-3.8	1.1
OB	0.6	0.4	0.2
GO	1.6	1.7	0.1
MPA	0.8	0.8	0.0

The only differences were seen in the variables TUI and MNSK. The upper incisors tended to tip slightly labially (TUI) in the open bite group, while they tended to tip slightly lingually in the deep bite group. Although these changes were in opposite directions, there was less than 0.5 mm of difference between the two.

Contrary to expected growth patterns, the Deep bite Control Group showed almost 30% more vertical mandibular growth (MNSK) than the Open bite Control Group. This can perhaps be partially explained by looking at the initial ages of both Control

Groups. The average initial age in the Deep bite Control Group was 11.2 years as compared to 12.8 years in the Open Bite Group. The period of investigation in Parker's study of deep bites was more centered on the expected pubertal growth spurt of adolescent patients. One could therefore expect to see more skeletal changes in this group.

Error Assessment

To assess the amount of investigator measurement error, ten traced radiographs were selected at random and all measurements were repeated. The measurement error was very small, with all reliability coefficients between 96% to 99%.

In addition to measurement error, investigator tracing error was assessed by retracing ten randomly selected radiographs. The tracing error was also very small, with the reliability coefficients for the means of all variables between 95% to 99%.

There is relatively quite a small amount of tracing and measurement error associated with the vertical analysis used in the present investigation. The analysis contains a small number of landmarks whose vertical positions are easily identified on a lateral cephalometric radiograph. From this rather simple analysis, an investigator can gain key information on the relative contributions of the skeletal and dental changes that occur between two radiographs.

SUMMARY AND CONCLUSIONS

The purpose of this investigation was to determine the relative contribution of various skeletal and dental components in open bite correction. Thirty-one patient records were selected from among the completed cases of the Department of Orthodontics at Case Western Reserve University. The cases were selected on the basis of zero vertical incisor overlap and no incisor contact at the start of treatment. In addition, all patients had adequate initial and deband radiographs. All patients had been treated with four first bicuspid extractions and fixed edgewise appliances. The treated group was matched by age, sex and treatment time with a sample of untreated open bite patients from the Bolton Collection, Cleveland, Ohio.

A cephalometric analysis (Parker 1990) which utilized six linear measurements and two angular measurements was used 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 from bodily movements of the upper and the lower incisors and assessed vertical skeletal changes in the maxilla and the mandible.

The following observations were made by analyzing the data:

1. Most of the open bite correction was achieved by lingual tipping of the upper and the lower incisors.

2. Lower facial height and mandibular plane increased slightly, having a negative effect on open bite correction.

3. Patients with open bite malocclusions exhibit an obtuse gonial angle and high mandibular plane angle.

4. At the completion of active orthodontic treatment, most patients showed some amount of vertical incisor overlap. However, in only about one fourth of the patients had an incisal overlap of 2.5 mm or greater been achieved.

5. A comparison between untreated open and deep bite patients showed surprisingly similar skeletal and dental changes.

APPENDIX

In addition to the present investigation, a pilot study was started to explore alternative treatment options for treating open bite malocclusions. The purpose of this study was to first fabricate, and then examine the effectiveness of a new orthodontic appliance in treating open-bite malocclusions. The effectiveness will be evaluated by comparing the treatment results from the new appliance to results achieved from thirty-one patients previously treated with fixed edgewise appliances and four bicuspid extractions.

The new appliance is constructed by attaching small magnets to an orthodontic appliance similar to a bionator. When the patient closes their teeth into the appliance, the magnets exert a repelling force which intrudes the posterior teeth and allows the anterior teeth to come together. After wearing the magnetic appliance for six months, the patients will be evaluated both clinically and radiographically for dental and skeletal changes. Lateral cephalometric radiographs taken after treatment will be superimposed and a cephalometric analysis completed on each lateral head film. These pre and post-treatment radiographs will be compared to pre and post

treatment radiographs of open bite patients treated with fixed edgewise appliances.

If effective, the magnetic appliance would be an alternative to the surgical correction of open bite malocclusions in certain patients. The non-surgical alternative would be beneficial to the patient in terms of reduced pain, psychological trauma, and recovery time. By reducing the treatment cost by several thousand dollars, the new magnetic appliance will provide a non-surgical alternative and enable a greater number of patients to receive treatment which would otherwise be too expensive.

Background

Studies by Dellinger (1986) using removable appliances and by Kalra et al., (1989) using fixed appliances showed that results similar to the surgical ones could be accomplished by using orthodontic appliances containing magnets. Both studies had similar appliances:

- -small samarium-cobalt magnets were embedded in acrylic and attached separately to the upper and lower arches
- -patients wore the appliances full time for four to six months
- -with the appliance in place, the patients were open about seven millimeters in the molar region

Although both studies showed dramatic results, there were some temporary side effects of the treatment. Since the magnets were attached separately to the upper and lower arches there was no single point where the jaws could repeatedly come together.

As the magnets exerted a repelling force on the teeth, the mandible was shifted to the side in response to the lateral forces generated by the magnets. When the appliances were removed, problems with crossbites existed.

Appliance Design

The new magnetic appliance is constructed by attaching small magnets to an appliance similar to a Bionator. Samarium-cobalt magnets were selected for this study because they are very powerful even in small sizes. The magnets are placed in a surgical stainless steel casing and sealed with a biocompatable epoxy to avoid breakdown in the oral environment. From the enclosed magnets extend 0.050 stainless steel posts which slide into 0.051 headgear tubes embedded into the acrylic of the bionator, allowing for free movement as the magnets repel.

When the patients close their teeth into the appliance, the magnets exert a repelling force which intrude their posterior teeth. As the patient's posterior teeth intrude, the open bite begins to close, and their anterior teeth can then come together.

Since the appliance is removable, the patients will be able to brush and floss their teeth when the appliance has been removed from their mouth. This aspect will allow the patient to maintain better oral hygiene during the study. A second advantage of the new design is that the appliance is indexed for the upper and lower jaws, preventing any side to side movement when the patient closes down. The indexing will prevent the

crossbites which occurred with previous design. As well as the indexing, the appliance design produces no lateral forces from the repelling magnets.

Components of the Appliance

-Samarian cobalt magnets

-Celcon plastic rails

-0.050 Stainless steel posts

-0.051 Headgear tubes

-Stainless steel casing

-Bionator framework

Appliance Fabrication

The decision was made to fabricate the casing to enclose the magnets in a two piece box-like container which could be sealed to prevent contamination with oral fluids. After consultation with the machine shop at Case Western Reserve University, it was determined that the two piece box casing could be most practically fabricated by using two separate dies to punch the top and the bottom of the "box" from precision cut blanks of stainless steel. Various samples of #304 annealed stainless steel which ranged from 0.010 to 0.005 inches in thickness were acquired from A.J. Oster Foils Inc., Alliance,Ohio, and evaluated for possible casing materials. The sample of 0.005 thick stainless steel was selected because it provided adequate rigidity, yet was thin enough to be stamped into a open box configuration using a simple die.

Two separate dies were designed and made at the machine shop of Case Western Reserve University to punch the top and the bottom of the "box" casing from precision cut blanks of stainless steel. The die for the top half of the box formed an open box which was slightly larger than the bottom, enabling it to fit snugly over the bottom half.

The samples of 0.005 inch thick stainless steel were precision cut into the blanks used for casing fabrication using a hot wire method by the Die Cut Products Company, Cleveland, Ohio. The cut blanks were basically rectangular in shape (0.695 x 0.940 inches) but had notched corners 0.0625 x 0.0625 inches. When a blank was placed into the appropriate die and pressed, the notched corners allowed the flat piece of steel to neatly fold into an open box configuration.

Plastic rails were placed on either side of the SmCo magnets inside the casing to provide added rigidity for the stainless steel posts. A sample of Celcon Plastic was acquired from Aetna Plastics Corporation, Cleveland, Ohio.

The two dies used in the casing fabrication were designed and fabricated by the machine shop at Case Western Reserve University. In addition to forming the top and bottom portions of the stainless steel casing, the dies served two other important functions. The dies were used to drill parallel holes through the casing and then to tap the stainless steel posts into place in a parallel configuration. The casings containing the SmCo magnets

and Celcon plastic side rails were sealed using Cyanoacrylate adhesive.

Once sealed the casings were placed back into the die so parallel holes could be drilled for the stainless steel posts. A high speed drill press was used to drill 0.045 inch parallel holes through the stainless steel casing and the plastic side rails. The 0.050 inch stainless steel posts were then tapped with a pressure fit into the slightly smaller holes. It was a major concern to have the posts as parallel as possible to allow for free sliding of the magnets within the headgear tubes.

Headgear tubes, which were six millimeters in length and 0.051 inchs in diameter, were embedded into the acrylic of the bionator framework. Small pieces of band material had to be spot welded to the headgear tubes to better lock them into the acrylic and prevent them from being dislodged.

Patient Selection

Two patients were selected for the study based on the orthodontic diagnosis of an open bite malocclusion. Prior to beginning any treatment, full orthodontic records were taken on each patient. These records included the following:

-medical and dental history

-oral examination including periodontal evaluation and TMJ screening

-intra and extraoral photographs

-alginate impressions for plaster study models

-frontal, lateral, and panoramic radiographs

-periapical radiographs of the molar regions

Treatment Proceedures

After full orthodontic records were taken and analyzed, the patients returned for alginate impressions and wax bite registrations needed to construct the magnetic appliance. When the patient received the appliance, both the patient and the parent were given instructions on proper appliance care. The patients were asked to wear the appliance between 12-14 hours per day for six months.

Evaluation of Results

The patients were evaluated both clinically and radiographically for dental and skeletal changes. During the study, the patients were evaluated in the orthodontic clinic every three weeks. The evaluation included:

-checking for proper fit of the appliance

-adjusting any sore spots

-measuring the distance between the patients' upper and lower anterior teeth

Since the goal of the treatment is to allow the patients' front teeth to come together, by measuring the distance between the teeth we can tell how close we were to reaching that goal.

Skeletal and dental changes will be evaluated by superimposing pre and post-treatment tracings of lateral head radiographs. By superimposing on stable landmarks of the

anterior cranial fossa, changes of the maxilla and mandible in relation to each other and to the rest of the skull will be evaluated. Dental changes of the jaws will be evaluated by utilizing maxillary and mandibular superimpositions.

At the time of this printing, clinically we have seen about one millimeter molar intrusion after four months of appliance wear.

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