CEPHALOMETRIC EVALUATION OF ORTHODONTIC TREATMENT OF EXCESSIVE OVERBITE

by

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Abstract

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This study evaluated the relative contributions of six skeletal and dental components in the orthodontic correction of deep overbite malocclusion in the growing patient. Thirty-one patients were selected from among the completed cases of the Department of Orthodontics at Case Western Reserve University (CWRU). Criteria for selection included excessive overbite (mandibular incisor beyond the cingulum of the maxillary incisor), four first bicuspid extractions, and fixed edgewise appliances using "Tweed" mechanics. The group was stratified according to facial type, age, and sex. Pre-treatment (T_1), and post-treatment (T_2) cephalometric radiographs were traced and measured. Thirty-one untreated deep overbite patients selected from the Bolton Study, CWRU, Cleveland, Ohio, were matched with the treated group according to facial type, age, sex, and treatment time.

Treatment effects were quantified using a vertical cephalometric

analysis composed of six linear measurements and two angular measurements. The six variables included maxillary skeletal change, tipping of the upper incisors, bodily movement of the upper incisors, mandibular skeletal change, lower incisor tipping, and bodily movement of the lower incisors.

The results indicated that most of the deep overbite correction was accomplished by bodily intrusion of the upper and lower incisors ($p \leq 0.001$). Significant improvement of overbite was obtained in all thirty-one cases, an average of 3.9 mm ($p \leq 0.05$). There also was a tendency for more intrusion as the face becomes shorter, implicating large symphyseal morphology and heavy muscular forces.

In conclusion, four bicuspid extraction using Tweed mechanics effectively limits vertical skeletal developement and maximizes the contributions of incisor intrusion to overbite correction.

DEDICATION

To Ann, Austin, my brother, and my parents. Thank you for all the love,support, encouragement, and prayers. I will never forget.

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INTRODUCTION

The correction of deep overbite is one of the primary objectives of orthodontic treatment. Deep overbite has been considered one of the most common malocclusions and the most difficult to treat successfully (Grieve 1928; Mershon 1937). Over time, disagreement has existed concerning the etiology of deep overbites and how they should be treated (Ricketts 1960; Merrifield 1970; Burstone 1977; Shudy, 1968). Furthermore, orthodontists have thought that the correction of a malocclusion is dependent on the individual's facial form as predicted by facial type indicators (SN-MP, FMA, angle mandibular arc, facial axis, and lower facial height) (Shudy 1968; Bench 1977; Engle et al. , 1980; Rickets 1960; Creekmore 1967).

Today there are many treatment modalities used to specifically open the bite, but only a few studies have measured the relative contributions of tipping and bodily tooth movements, and skeletal changes, while controlling for normal growth. To address how a deep overbite can be corrected, we must look at four contributing factors: 1) molar extrusion 2) incisor intrusion 3) tipping of the incisors and 4) differential growth of the maxilla and mandible (Simons and Joondeph 1973; Engel 1980).

The correction of deep overbite involves changes in the position of the teeth, the maxilla, and the mandible. These parameters have all been

studied by various cephalometric analyses. Some methods account for changes in growth by adjustment with a numerical factor (Thompson 1979, Otto 1980) while others use regional superimposition and comparison with untreated control samples (Creekmore 1967; Weislander 1974). Although many different methods have been proposed for the correction of deep overbite, the relative contributions of tipping and intrusive tooth movements, skeletal change, and growth in cases undergoing extraction of teeth still remain unclear. Furthermore, superimpositional methods have been limited to qualitative results and individual amounts of tooth movement have not been shown. Many investigators have developed cephalometric measurements to evaluate amounts of intrusion or depression of the dental units. However, until recently, true vertical changes in incisor position were impossible to assess since labial tipping components were not separated from pure intrusion. It has been recognized that tipping changes influence incisor vertical height but many investigators did not account for the interaction of these variables (Barton 1972; Otto 1980; Engle et al., 1980).

Due to the importance of the vertical dimension in orthodontic treatment, Hans (1994), Parker (1990), and Kishiyama (1987) at Case Western Reserve University, devised a method of analyzing true vertical changes that occur with treatment during tooth movement and skeletal growth. In each of their studies, deep overbite correction was examined using the vertical cephalometric analysis. Comparisons of treatment modalities and effects on facial type were made using pure nonextraction or

partial extraction samples. It is this same analysis that Dietrich (1992) used to study the effects of orthodontic vertical correction of open bite malocclusions. Thirty-one treated patients with four first bicuspid extractions were compared to an orthodontically untreated matched control group (n=31). The observations made by analyzing the data included correction of the open bite mostly by lingual tipping of incisors while the lower facial height and mandibular plane increased slightly, having a negative effect on open bite correction. It is the aim of the present study to again utilize the vertical analysis to assess changes in overbite that specifically accompany four first bicuspid extraction treatment. Moreover, the study will report on the effect of four first bicuspid extractions, Tweed mechanics, and facial type on the relative contributions of tipping, intrusive and extrusive tooth movements, and vertical facial growth in the correction of deep overbite malocclusion.

LITERATURE REVIEW

The correction of deep overbite is one of the main objectives of orthodontic treatment. Deep overbite has been thought to be one of the most prevalent malocclusions and the most difficult to treat successfully (Mershon 1937). Goldstein (1936) found the amount of vertical overlap often varies excessively and is one of the most common early evidences of malocclusion. Strang (1950) established the common definition of overbite as "the overlapping of the upper anterior teeth over the lowers in the vertical plane".

There are several different views as to the proper amount of vertical overlap of the maxillary and mandibular incisors. Normal or correct overbite has been measured in percentages, millimeters, and in certain anatomical relationships. It was reported by Neff (1949) that the ideal overbite was 20% overlap, while others have recorded overbite ranges of 35 - 40%. Williamson (1976) explained that the ideal incisor overlap was accomplished when the incisal edge of the lower incisor rested on the cingulum of the upper central incisor. Following the requirements of a functional occlusion, an overbite was defined to be extreme when the lower incisal edge was beyond the cingulum of the maxillary incisor. Steadman (1952) made linear measurements of overbite and found a range from 0.5

mm to 4.3 mm with a mean of 3.1 mm. In his studies of ideal dental and skeletal relationships, Ricketts (1982) found the mean values for overbite to be 2.5 mm.

Development of Deep Overbite

There are several factors that appear to be related to the development of deep overbite. These include incisor supraocclusion, excessive overjet, mesiodistal width of the anterior teeth, incisor angulation, canine position, molar infraocclusion, molar cusp heights, failure of natural opening of the bite, mandibular ramus height, and vertical facial type. There still remains much controversy as to the definition and etiology of deep overbite. Parker (1990) in a cephalometric study, defined excessive deep overbite by the extension of the lower incisor edge beyond the cingulum of the maxillary incisors.

Bonwell (1925) believed the depth of the posterior cusps determined the amount of anterior overbite. Steadman (1949) examined the relationship of the maxillary anterior teeth to the mandibular anterior teeth and found overbite was directly proportional to interincisal angle. Popovich (1955), studying Class I and Class II deep overbite groups, reported that a positive relationship existed between interincisal angle and overbite. Comparatively, Buckland (1958) reported the angle between the lingual surfaces of the upper and lower incisors to correlate best with stability of a corrected deep overbite.

Jackson (1939) implied that vertical eruption of maxillary and

mandibular incisors was the cause of overbite. Wolfson (1938) reported only the lower incisor vertical height to be linked with overbite.

Several authors (Strang 1934; Mershon 1937; Steadman 1952) believe that a combination of infraeruption of the posterior teeth and supereruption of anterior teeth produce a deep overbite. Future support came from Prakash and Margolis (1952) in a cephalometric study showing positive correlation between upper incisor height and overbite, and a negative correlation between eruption of lower molars and overbite. Proffit (1992) states that overbite results from over eruption of the lower anteriors, especially in Class II retrognathia. Barton (1972) believed that neuromuscular features played a role and the extent of posterior and anterior tooth eruption was eventually determined by muscular forces.

Fleming (1961) attributed excessive overbite to mandibular ramus height. From a cephalometric and plaster model study, he described a significant negative correlation between ramus length and degree of overbite. Diamond (1944) also studied vertical development of the mandibular ramus and its correlation to dental height of the dentition. He observed that deficient growth in the length of the ramus would retard the active eruption of the posterior teeth and allow the further eruption of the anterior teeth causing a deep overbite.

In testing Diamond's belief, Wylie (1946) found disagreeing results. Three sample groups were used to compare ramus height. Between the groups with slight overbite (1.5 to 2.0 mm), medium overbite (over 2.0 mm

but incisal of the maxillary cingulum) and severe overbite (where the mandibular incisor occluded on the cingulum or beyond) no significant differences in ramus height were found. In addition, Wylie (1964), Popovich (1955), and Mills (1973) all reported that face height, lower face height, and molar height were significantly less in cases with severe overbite than in those with slight overbite.

Trouten (1980), using Enlow's counterpart analysis, studied normal, untreated deep overbite and openbite cases. The following traits of a deep overbite were reported: a closed gonial angle, upward aligned mandibular plane, flatter occlusal plane, deeper curve of spee, decreased palatal depth (from ANS to the midline of the palate), greater ANB angle, greater maxillary protrusive tendency, less posteriorly aligned ramus, decreased PM dimension, upward corpus-occlusal rotation in relation to the ramus rotation, and a clockwise rotation of the palatal plane during vertical growth of the nasomaxillary complex. Trouten also found that when the Class I and Class II cases were separated in the study, there were no significant differences. The angle classification was not considered as a sample criteria.

Schudy (1963) reported another view on overbite development. He associated an increasing in ramus height with a deepening overbite. His sample involved deep overbites with Class II retrognathia and large rami.

Bjork (1969) in a longitudinal cephalometric study, devised a way to predict mandibular growth rotation. Metallic implants were placed in the jaws of one hundred subjects and a list of structural signs were noted. From

these, a prediction of forward rotation associated with a skeletal deep bite could be made. Bjork stated that not all of the signs must be present, but the greater the number present, the greater the predictability. The following are the signs:

1. a forward vertical inclination of the condylar head
2. a curving mandibular canal following the angle of the jaw
3. a convex of pronounced appositional rounding of the lower border of the mandible
4. a prominent chin button, and upright inclination of the symphysis
5. increased interincisal angle
6. perpendicular or no mesial inclination of molars or premolars
7. decreased lower anterior facial height (compression)

Bjork did not use the mandibular plane angle as a predictor due to evidence from his implant studies that the lower boarder of the mandible underwent significant remodeling which made it an unreliable predictor of mandibular growth rotation.

Richardson (1969) examined lateral cephalometric radiographs of 110 deep overbite cases and 110 openbite cases. The upper facial heights were similar but there was a decrease in lower facial height in the deep overbite cases compared to the openbite cases. He reported that as the ramus height and mandibular body length both increased, the jaw angle compensated by closing and the lower facial height maintained or decreased. Richardson, as well as Moss and Salentijin (1971), all consider

the shape of the mandible to be more important than size or dimension in the deep overbite patient.

The cause of deep overbite malocclusion can be an amalgamation of skeletal, dental and muscular factors as supported in the literature. Mershon (1937) divided deep overbites into two categories:

1. true closed bites which were associated with infraocclusion of molars and strong musculature, making correction impossible
2. deep overbites due to supraocclusion of incisors, which can be successfully treated with intrusion

Baume (1950) concluded that the anterior-posterior mandibular growth was important in determining overbite. He observed that deficient forward growth of the mandible during incisor tooth eruption was associated with deep overbite. Grieve (1928) stated deep overbites were an antero-posterior problem caused by protrusion of maxillary teeth, a deficient mandible, or both.

Strang (1934) and Hemley (1938) maintained that deep overbite relationship was attributed to problems in posterior and anterior vertical tooth eruption. They implicated muscular forces in molar infraclusion and incisor supraclusion causing deep overbite.

Popovich (1955) in a cephalometric study, attributed Class I deep overbites more to dental factors. In Class II malocclusions, skeletal factors such as short ramus and facial height in conjunction with dental factors were thought to produce the deep overbite.

Sassouni and Nanda (1964) examined the vertical proportions of the

face by studying 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 deep bites as compared to skeletal open bites:

1. the position of the condyles is lower in the deep bite cases
2. the ramus is longer in the deep bite cases
3. the maxillary molars are higher in the deep bite cases

They felt these three factors were basic differences causing the other "symptoms" of the skeletal deep bite: a decreased lower facial height, lower mandibular and occlusal plane angle, and acute gonial angle.

Sassouni and Nanda summarized several factors related to deep overbite that were cited by other authors. Among these characteristics associated with deep overbite were large cusp heights of posterior teeth, short molar height, upright incisors, short total anterior facial height, short anterior lower face height, horizontal mandibular occlusal and palatal planes, small gonial angle, and increase of freeway space. Sassouni and Nanda concluded that the imbalances in the vertical dimension were more significant and should be addressed first to correct the anteroposterior imbalances.

Proctor and DeVincenzo (1970) studied the theories of muscle forces and attachment sites in skeletal open and deep bites. They found that the positions of the masseter muscle fibers were different in relation to Frankfort, SN, palatal and mandibular planes. Moss and Salentijn (1971), from

another viewpoint, believed that the masseter muscle position is normal but it is the capsule surrounding the muscle that is atypical in skeletal deep bites.

Sassouni and Nanda (1964) instead believed that the muscles of mastication exerted different levels of function and force vectors in malocclusions. In the deep bite patient, the muscle forces are directed more anterior and more perpendicular, applying more force over the molars causing infraeruption.

Carlyle (1977) in a cephalometric study of overbite relationships, reported that there was no connection between increased incisor dentoalveolar vertical height and deep overbite. He did show that deep overbite is associated with reduced dentoalveolar vertical molar height, retrusive lower incisors, and a small retrognathic mandible relative to the maxilla as well as the cranial base.

Facial Pattern and Overbite

In 1964, Schudy coined the term "hypodivergent" to describe low angle cases and "hyperdivergent" to describe high angle cases. Schudy found that the hypodivergent facial type could be characterized by a low mandibular plane angle, decreased facial height, and decreased occlusal-mandibular angle. The opposite features apply to hyperdivergent cases. In 1963 and 1966, Schudy reported the occlusal-mandibular plane angle (OM) to have a significant correlation with vertical overbite. He found that the amount of overbite was significantly dependent on facial form. Then in

1968, Schudy, after following Creekmore's (1967) work, supported the idea that facial type was more critical in determining a patient's response to orthodontic treatment than the amount of overbite present.

Bjork (1947) studied the relationship between the mandibular plane and the occlusal plane. He found that groups with a smaller occlusal-mandibular angle had larger overbites.

Wylie (1946) examined the relationship between total facial height and vertical overbite. He reported that the total facial height decreased as the overbite depth increased.

Ludwig (1967), following Shudy's methodology, studied a sample of forty-one cases, all with deep overbite. His findings were not in agreement with Shudy's, as he claimed "there was no significant correlation between pretreatment overbite and the facial pattern of an individual".

Creekmore (1967) evaluated the effects of orthodontic treatment on vertical development of the face. His study involved untreated controls and treated cases. In the control group, he found that vertical eruption of teeth is not uniform. In comparison, the orthodontically treated sample showed significant extrusion of the mandibular molars and relative intrusion or inhibition of the mandibular incisors. Vertical dimension and facial form increased as the bite opened.

Creekmore (1967) also studied a sample of high and low mandibular plane angles. He reported high angle cases without orthodontic treatment were more likely to develop vertically than average facial types, and the low

angle facial types were more likely to be less responsive than the average. The low angle facial types tended to decrease with growth. Creekmore believed that deep overbites were difficult to treat. He suggested that due to the resistance of vertical posterior eruption, a practitioner must depress the anterior teeth that are already infraerupted. He stated different facial types need to be treated differently.

Furthermore, Shudy (1968) discovered a strong correlation between bite opening potential and the occlusal-mandibular plane angle. He believed that a patient's facial type was more important than the amount of overbite in determining a patient's response to treatment.

Bjork and Skeiller (1972) in a metallic implant study, showed that deep bite treatment should be corrected in relation to different facial types and mandibular growth rotation. Dolichofacial cases tended to have less mandibular molar eruption than brachyfacial cases and greater incisor eruption. However, they also stated that a high mandibular plane angle is not a good predictor of facial growth. A patient with a high mandibular plane angle could have either a backward or forward mandibular growth pattern.

In additional studies, the influence of facial type on the orthodontic treatment of overbite was explored by Ricketts (1964), Burstone (1977), and Bench et al., (1978). Each examined the intrusion of lower incisors to correct a deep overbite. Ricketts described a correlation between the morphology of the symphysis and the difficulty of intruding lower incisors. He believed that high angle or dolichofacial cases have long thin symphyses, while

brachyfacial cases have wider, square symphyses. Bench, Gugino, and Hilgers (1978) also stated that dolichofacial patterns were characterized by narrow symphyses and labial tipped incisors, making intrusion mechanics ineffective. Brachyfacial types with a larger mandibular alveolus allowed for incisor positioning, which is advantageous to lower incisor intrusion.

In opposition, Otto et al., (1980) found neither age nor facial type had significant influence upon the amount of intrusion. Review of this study revealed a suspect sample size and experimental design.

The issue of incisor intrusion or molar extrusion in extreme facial types has been addressed by many in the past. Ricketts (1960) and Burston (1977), along with others, agreed that for very short faces posterior eruption is indicated, whereas in long faces posterior extrusion is not the treatment of choice. But when presented with a patient of average facial pattern, the question of incisor intrusion or molar extrusion is difficult to answer. On one side, Engel (1980), Burstone (1977), Dellinger (1967), and DiGiulio (1983) all advocate some type of intrusion mechanics involving maxillary or mandibular incisors. On the other side, Schudy (1963), Creekmore (1967), and Dake and Sinclair (1989) represent the advocates of extrusion of posterior teeth. Otto (1980) believed that overbite reduction included more than intrusion alone. He described incisor intrusion, increased facial height, along with labial flaring of incisors during treatment, to be the main elements of overbite correction. Engle (1980) in a review reported that deep overbite correction involved incisor intrusion, incisor proclination, and mandibular

rotation. He also stated that treatment of deep bite cases during a growth period can be advantageous if controlled properly. In certain orthodontic techniques, if not all, it is probable that a combination of molar extrusion, incisor intrusion, labial flaring, and jaw rotation is attained.

In determining the relative contribution of normal growth and orthodontic treatment effects, many researchers have utilized various techniques to separate growth from treatment changes. Since Bjork's (1953) study, one must be aware that overbites can improve in time to some degree without treatment. This present study, as well as others, (Parker 1990; Dietrich 1992; Lawrence 1985) have utilized untreated matched controls.

Johnston (1986) in analyzing different treatment modalities and the effects on Class II correction, used Rocky Mountain Data System's sex specific growth curves and calculated a coefficient termed "expected growth units". These units were based on age, sex, and length of treatment depicting an untreated individual's growth potential.

Otto (1980) made computations to correct for the amount of holding against vertical growth or relative intrusion in the growing patient. The growth effects were figured by subtracting the change at anterior nasal spine from the change at suprapogonion. This quantity was the total extrusive effect of growth, thus only the total combined incisor intrusion could be quantified.

Thompson (1979) in evaluation of Begg technique, studied the

positional changes in the maxillary and mandibular incisors, as well as the mandibular molars relative to the overbite and occlusal plane. He also devised cephalometric measurements that represented growth regions that could be factored out to find the actual treatment effect.

In a recent study (Chua et al., 1993), examined the effects of orthodontic extraction treatment on the lower anterior face height. They were able to control for the effects of growth by normalizing ANS-ME measurements to the Michigan Growth Standard. This method allowed for comparison of subjects with different pre-treatment ages, as well as others whose treatment duration is different. This also allows for a larger sample.

In general most studies, if controlling for growth, use subjects in the same age group. Some studies have not factored out growth whatsoever (Parker, Nanda, Currier 1995; Barton 1972; Carlyle 1977). Obviously, it is essential to have some method to separate treatment effects from normal growth.

Change in Overbite Due to Growth

Many researchers (Baume 1950; Bjork 1953; Moorees 1959; Herness 1973; Moyers 1976) have studied the changes in the amount of overbite of the incisors with growth. However, due to marked individual variability there still remains lack of agreement among investigators concerning age and the increase or decrease of overbite.

Bjork (1953), in a longitudinal study of boys, followed the variation in growth occurring between the ages of twelve and twenty years. He found

there was a general decrease in the overbite with age and that deep overbites had a greater tendency to open more than normal overbites. High individual variation was noted. Schudy, from a study in 1968, found several anatomic factors affecting overbite. Listed were the condyles, maxilla, posterior alveolar process of the maxilla and mandible, and the vertical growth of the anterior process of the maxilla and mandible. Shudy believed that since downward maxillary growth accounted for 70% of total vertical growth of the face, this was the most prominent factor in creating facial height and affecting overbite.

Bjork and Skeiller (1972), using implants, showed the increase or decrease of overbite in relation to the growth rotation of the mandible. McNamara (1986) stated that in an adolescent patient with normal growth and development, one would expect the mandibular plane angle to decrease one degree every three to four years, thus having a bite closing effect.

Vertical Effect of Orthodontic Extraction Treatment

A practitioner today is often times confronted with the decision to extract premolar teeth. This choice is usually dictated by excessive crowding, deep curve of spee, and incisor angulation in the mandibular arch. However, there is disagreement and confusion concerning the effect of bicuspid extraction on the vertical dimension. It has been proposed by many that the extraction of premolars allows the posterior teeth to move forward orthodontically, resulting in reduction of the vertical dimension. The

overclosure of the mandible then foreshortens the musculature causing the muscles to work incorrectly and to result in fatigue and pain (Witzig 1987; Tully 1959; Wilson 1971). Other reports, however, do not support this view (Cusimano et al., 1993; Dougherty 1968; Staggers 1990 and 1994; Klapper 1992). These studies show that if bicuspids are extracted in cases with low mandibular plane angles, there is no change or a small decrease in the vertical dimension, but in cases with higher mandibular plane angles there is a slight marked increase.

In a study analyzing a structural method for prediction of mandibular growth rotation, Bjork (1969) considered the clinical aspects. He stated that the more extreme the rotation of the mandible, the greater the clinical problems. In a severe forward rotation, there is a greater risk of deepening the developing bite. He advised delaying extractions until at least the puberal growth spurt.

Shudy (1963; 1964; 1966; 1968) described the vertical components of facial growth and recommended various treatment options. He advised that a hypodivergent facial pattern be treated with nonextraction and a hyperdivergent facial type be treated with extraction. He believed extraction of teeth closed the bite. Sassouni and Nanda (1964) had a similar treatment philosophy.

Pearson (1973) studied a series of extraction cases and found an increase in lower molar height of 3.2 mm and referenced Dougherty (1968) as reporting a similar value of 3.5 mm of extrusion in molars undergoing

Tweed anchorage preparation. When Pearson treated a second set of extraction cases with lower headgear, there was only 1.9 mm average increase in lower molar height and a mean decrease in the mandibular plane angle of 3.9°. He suggested it takes unique effort, in addition to extraction treatment, to reduce the vertical. In 1986, Pearson examined seventy-nine patients with backward growth rotation patterns to be treated with a vertical pull chincup. The patient sample consisted of fifty-one extraction cases and twenty-eight nonextraction cases, each with fixed Edgewise appliances with all molars banded. Generally, the nonextraction cases showed half the amount of molar extrusion than did the extraction cases. Facial height did increase in both groups to the same extent, while the mandibular plane angle decreased (1.4°) in the extraction group and increased (0.6°) in the nonextraction group.

Chua (1993) examined the effects of extraction and nonextraction orthodontic treatment on the growth of the lower anterior face height (ANS-ME). A sample of 174 patients was divided equally into Class I and Class II cases, forty extraction and forty-seven nonextraction in each class. A linear cephalometric measurement from anterior nasal spine to menton was calculated for each case before and after treatment. Growth was factored out by normalizing ANS-ME measurements to the Michigan Growth Standard. The results showed that nonextraction treatment in both Class I and Class II subjects significantly increased the lower facial height and is associated with the downward, backward rotation of the mandible. Even

with a longer average treatment time, extraction treatment was not related to any changes in lower anterior facial height suggesting that extraction alone is not effective in decreasing the lower anterior facial height.

Dietrich (1992) in a study of thirty-one open bite malocclusions with four bicuspid extractions noted that despite removal of teeth, there was still a statistically significant increase in lower facial height and slight opening of the mandibular plane. Reference was made to Isaacson et al., (1971) stating that anchorage loss present in space closure following premolar extraction should have taken place, having a positive effect on bite closure. There were no differences in the vertical position of the maxilla, and the gonial angle decreased. Thus the mandibular skeletal increase was attributed to extrusion of the buccal segments.

Cusimano (1993) examined cephalometric radiographs to further investigate the changes in mandibular plane angles in thirty-one high angle patients treated with the extraction of four first bicuspids and protraction of the posterior teeth. The sample consisted of Class I and Class II occlusions, sixteen boys and twenty-one girls. A modified mandibular plane was constructed based on stable landmarks, and a constructed horizontal reference plane on a millimeter grid measured mandibular dental changes. The results showed 3.2 mm of upper molar extrusion and 2.2 mm of lower molar extrusion. Growth was considered to be approximately 1.9 mm of vertical movement of the maxillary molar and 1.6 mm of that of the mandibular molar according to Schudy (1968). The occlusal movement of

the posterior teeth kept pace with the increase in anterior facial height causing the mandibular plane angle to remain constant and canceling out the bite-closing effect of posterior protraction. Essentially, the gonial angle stayed parallel to its pre-treatment position.

Staggers' (1994) findings did not support the theory that extraction of the first premolar produces a loss in the vertical dimension of occlusion. Forty-five nonextraction and thirty-eight first premolar extraction patients were selected. All were skeletal and dental Class I. The pre-treatment and post-treatment lateral cephalograms were traced and digitized. Orthodontic treatment in both the extraction and nonextraction groups resulted in a minor increase in mandibular plane angle, extrusion of maxillary and mandibular first molars, and an increase in the anterior facial height. Only seven of the eighty-three cases had a decrease in the anterior facial height dimension. No control was used in the study.

Parker, Nanda, and Currier (1995) conducted a retrospective study of 132 treated orthodontic cases with deep overbite malocclusion using dental casts and cephalometric radiographs from pre-treatment to post-treatment. These were sixty-one Class II; twenty-seven Class II, Division I and forty-four Class II, Division 2 malocclusion cases. Six different treatment modalities for the correction of deep overbites were studied. The data were then grouped according to Angle classification and patients were also separated according to whether the permanent teeth had been extracted. Results showed that the extraction of teeth did have significant effect on the changes

examined with treatment in all the Angle classes and more so in the Class I sample. Maxillary and mandibular first molars consistently extruded. Mesial movement of the molars was more in extraction treatment and proclination of the incisors was less. No statistically significant differences were observed between the various treatment mechanics. Only in the Class II, Division 2 sample, total anterior facial height increased significantly with all treatment modalities Both total anterior face height and lower face height increased in all cases.

Klapper et al., (1992) examined the effects of extraction and nonextraction orthodontic treatment mechanics on individuals with dolichofacial and brachyfacial growth patterns. Two groups of thirty were treated of either nonextraction or extraction of four bicuspids with suitable mechanics for the facial type. Changes in the facial axis as well as a correlation between maxillary molar movement and facial axis change were measured. Results showed that upper molar movement was correlated with opening or closing of the facial axis in nonextraction treatment in both facial types. In extraction treatment groups, a weak correlation was found. Regardless of facial type or treatment plan, there was no statistically significant difference found in facial axis change among any of the groups studied. All the treatment mechanics were based on recommendations cited previously in journals. For example, in brachyfacial patients, cervical headgear and Class II elastics, and in dolichofacial patients, high-pull headgear and minimal Class II elastic use. Klapper concluded that a

practitioner can treat these patients with or without extractions and still be able to avoid adverse changes in the facial axis with appropriate mechanics.

Assessment of Vertical Tooth Movement

In order to study vertical incisor movement, awareness of the different interpretations and definitions of intrusion or depression is important. In 1962, Thurow stated that as the mandibular incisors are tipped forward the incisal edges will also tip downward on the arc of rotation, thus clinically appearing as intrusion. He called this movement a "tipping depression." Later on, McDowell (1970) defined true intrusion, while Burstone (1977) termed "the labial tipping of an incisor around its centroid" as "pseudo-intrusion".

Sassouni and Nanda (1964) defined depression as relative to growth. They explained that by holding the tooth while the alveolar process is growing occlusally shows relative depression of the teeth and is only likely to occur in the growing patient.

Although the established definition of genuine intrusion was stated as the translation of incisors along their long axis, Liu and Herschleb (1981) defined tooth movement by their horizontal and vertical components within a coordinate system as well as axial inclination. They recommended their definition as pure intrusion consisting of pure vertical displacement of the center of resistance where the axial inclination of the tooth stays constant.

In the measuring of intrusions, there are different methods used. Creekmore (1967), Parker et al., (1995) and others used perpendicular

lines from anterior nasal spine to upper incisal edge and mandibular plane to lower incisal edge to measure the vertical behavior of the maxillary and mandibular incisors, respectively.

Otto (1980) studied the effects of a bioprogressive technique on the intrusion of incisors in adults and children according to facial type. Templates were used to trace the incisors by registering on the incisal edge and aligning to the long axis allowing uniform transferring of tooth position. After maxillary and mandibular superimposition, measurements at the root apices assessed intrusion and long axis of tipping changes. This measurement technique was intended to evaluate bodily intrusion at the apex which is less affected by tipping but suffers from root resorption.

Liu and Herschleb (1981) in their study used a cephalometric analysis that involved measuring intrusion from the center of resistance, defined as 40% of the root length. Root length was measured as the distance from the alveolar bone crest to the root apex.

Burstone (1977) believed that intrusion is best measured from the centroid of the tooth. This avoids the limitation of measurements involving the incisal tip, which is most affected by tipping changes and root apices that are often affected by external resorption.

Kishiyama (1987) noted that few studies attempted to evaluate intrusion without separating vertical changes due to dental tipping. Using the defined center of resistance by Liu and Herschleb (1981), he formed an analysis addressing these issues.

STATEMENT OF THESIS

The objective of this study was to evaluate the effect of four first bicuspid extraction Tweed Philosophy orthodontic treatment for correcting deep overbite malocclusions in growing patients. Molar extrusion, incisor intrusion, tipping of the incisors, and differential growth of the maxillary and mandibular structures are four interrelated factors that can contribute to overbite correction. It is also considered that the facial type of a person influences the contribution of growth and treatment effects to the orthodontic correction of deep overbite.

At present, the problem of quantitatively determining the effective means of overbite correction in extraction cases is longstanding and unresolved. This research is important since the precise nature of tooth movements that combine to correct a deep overbite has not been determined due to a lack of an adequate method that can quantitate the relative contributions of orthodontic dental, skeletal, and growth changes. Many previous studies have been characterized by small samples, poor methodology, or lack of controls. Hopefully, this study will aid the clinician in making rational decisions toward treatment of vertical deviations such as deep overbite.

MATERIALS AND METHODS

Sample

This study examined the cephalometric records of thirty-one patients treated by residents at CWRU's Orthodontic Department. Criteria for selection consisted of the availability of adequate pre-treatment (T_1) and deband cephalograms (T_2). All subjects had a pre-treatment condition of 70 - 100% deep overbite and treatment included extraction of four first bicuspids and fixed 0.022″ edgewise appliances (Tweed mechanics). To avoid outcome bias patients were selected strictly from an evaluation of pre-treatment radiographs. Overbite was considered excessive if the incisal edge of at least one lower incisors was at or beyond the cingulum of the maxillary incisor. This was determined cephalometrically, but if further confirmation was needed, the pre-treatment models were examined.

The treated sample was divided according to facial type by the use of anthropometric values (Hredlicka 1947): euryprosopic (wide and short), mesoprosopic (intermediate), and leptoprosopic (narrow and long). To determine the facial form, the availability of both lateral and frontal cephalograms was necessary since the facial index was calculated as the ratio of the skeletal length from Nasion to Menton divided by the Bizygomatic width (Parker 1990). Measurements were made with a millimetric ruler

accurate to the nearest 0.1 mm. Facial form was then determined from a facial index defined by Hredlicka (1947) as follows:

Hypereuryprosopic xx.x-79.9

Euryprosopic 80.0-84.9

Mesoprosopic 85.0-89.9

Leptoprosopic 90.0-xx.x

For patients where frontal cephalograms were not available, the clinical frontal and profile photographs (2 1/2 x 3 1/2 inches) were used to measure the soft tissue facial index. Kishiyama (1987) and Parker (1990) found that using clinical photographs was a valid method of measurement.

The control sample consisted of thirty-one orthodontically untreated subjects with deep overbite from the Bolton Study (CWRU). Control sujects were classified by facial type in the same manner as the treatment group. All cases in the control group had frontal and lateral head films available. This study used untreated matched controls.

Patients were stratified on the basis of facial type, age, sex, and overbite but not on Angle classification since Trouten (1980), using Enlow's Counterpart Analysis (1982), found no significant differences between Class I and Class II cases with deep overbite. Female patients over fourteen and males over the age of eighteen, when started for orthodontic treatment, were excluded from the experimental sample since their age indicated the possibility that facial growth may be occurring very slowly (Broadbent et al., 1975).

Cephalometric Analysis

Once selected, all radiographs were traced on 0.003 inches matte acetate with a 0.5 mm lead mechanical pencil. In all tracings, bilateral anatomical landmarks were bisected and the midpoint taken to reduce all landmarks to their midsagital value allowing identification of sixteen registration points according to Parker (1990) (see Table 1 and Figure 1). Descriptive and inferential statistical analyses were used to compare pre- and post-treatment values.

The two cephalograms for each individual were labeled as follows:

T_1 = Pre-treatment film C_1 = Time one control film

T_2 = Deband film C_2 = Time two control film

All the landmarks were traced directly from T_1 (or C_1) and T_2 (or C_2) radiographs with the exception of the center of resistance (CR) for the upper and lower incisors and the fiducial reference plane. The CR for the incisors was arbitrarily set at 40% of the distance from the alveolar crest to the root apex. The CR point was transferred from Time 1 to Time 2 tracings using a template (Liu and Herschleb 1981). This distance was measured with a digital caliper accurate to the nearest 0.1 mm and was marked on the long axis of each incisor at T_1 (or C_1). The CR point was transferred to the T_2 tracing by registration on the incisal edge.

A superimpositional method was applied by utilizing the sphenoethmoidal junction and the anterior cranial base to evaluate

Table 1.--Landmarks Traced

1. Sphenoethmoidal Junction (SE)
2. *Forament Rotundum in the Pterygomaxillary Fissure
3. Inferior-most Point of the Pterygomaxillary Fissure
4. *Three (3) mm Above Orbitale
5. Posterior Nasal Spine (PNS)
6. Anterior Nasal Spine (ANS)
7. Center of Resistance (CR) of the Upper Incisor
8. Incisal Edge of the Upper Incisor
9. Most Posterior Occlusal Point of the Last Fully Erupted Maxillary and Mandibular Molars
10. Most Anterior Maxillary/Mandibular First Premolar Occlusal Contact
11. Incisal Edge of the Lower Incisor
12. CR of the Lower Incisor
13. Articulare (AR)
14. Intersection of AR-GO with Functional Occlusal Plane (FOP)
15. Gonion (GO)
16. Menton (ME) and Symphyses

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

anatomical change from Time one (T_1) (C_1) to Time two (T_2) (C_2). When all landmarks were traced, a fiducial horizontal reference line was constructed from pterygoid (Pt) point to a point 3 mm above orbitale (Baumrind and Miller 1980). This fiducial line was then transferred to the Time 2 cephalogram (T_2 or C_2, respectively) tracings by superimposing the T_2 (or C_2) tracing on the T1 (or T_2) tracing using the spenoethmoidal junction and the anterior cranial base, as stable landmarks (Bjork 1955, and Elmejian 1959). Regional superimpositions on the maxilla (Nielsen 1989) and the mandible (Bjork 1963) were utilized to discriminate between skeletal rotations and dental tipping when evaluating treatment effects.

Six linear distances were measured. From these measurements seven variables were calculated, thus forming the basis of the analysis (Dietrich 1992) (see Figure 1). All linear distances were measured from a perpendicular fiducial reference line, pterygoid point to point 3.0 mm above orbitale (T_1 and C_1), and constructed pterygoid point to orbitale +3.0 mm (T_2 and C_2). As previously discussed, the constructed plane was transferre from the initial tracing by superimposition on the sphenoethmoidal junction and the anterior cranial base. The linear measurements were made to the nearest 0.1 mm using a Mitutoyo "Digimatic" electronic digital caliper (Mitutoyo Corporation, Japan). All angular measurements were made to the nearest 0.5° using a Ricketts orthodontic template (Dome Manufacturing Co., Tarzana,CA.).

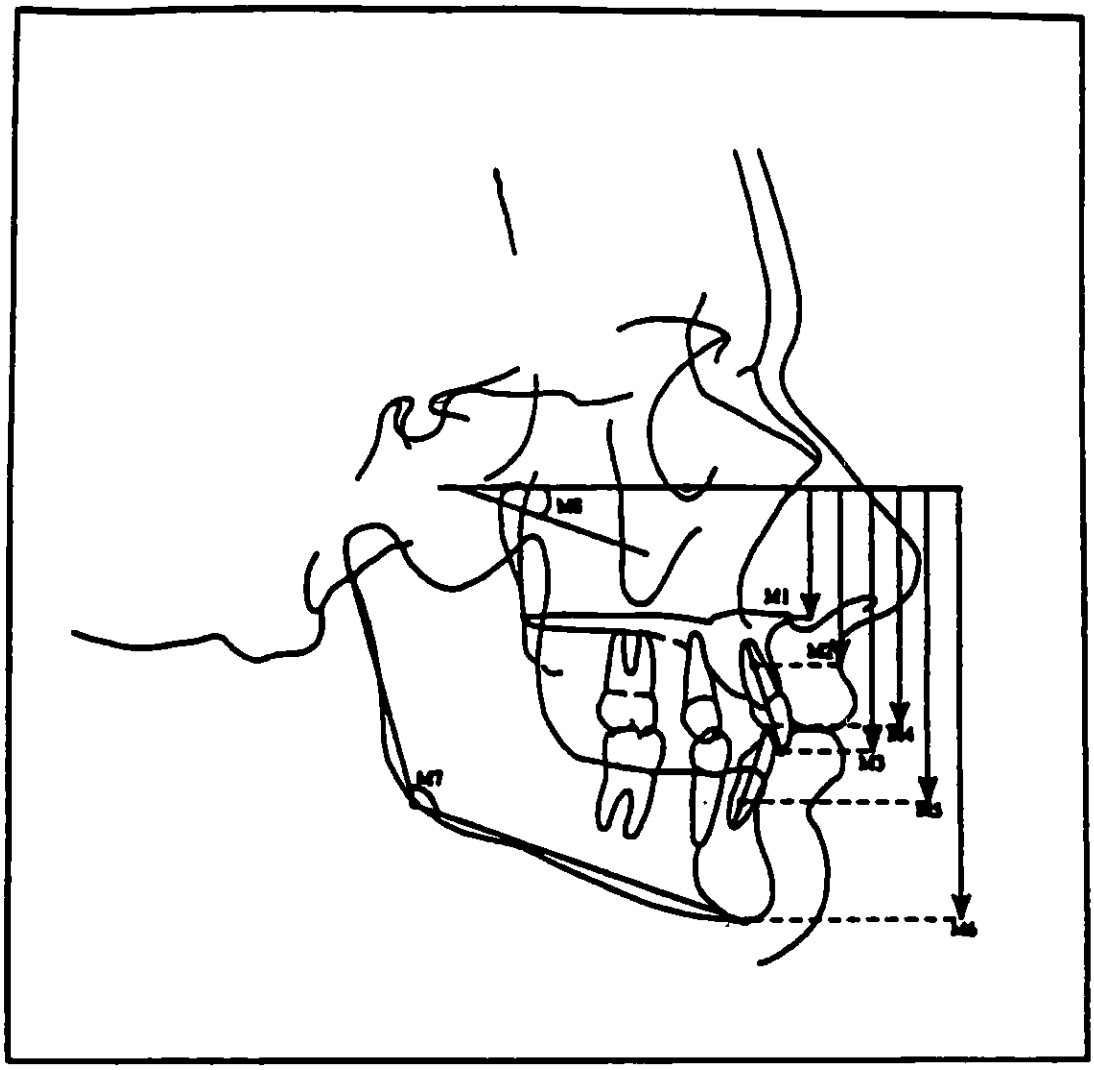


Figure 1. Cephalometric Tracing with Linear and Angular Measurements.
(Anterior Vertical analysis used in the study)

The following abbreviations were used to represent the linear measurements in the anterior vertical analysis (see Figures 1 and 2):

Measurement 1 (M_1):	Distance from the reference line to anterior nasal spine (ANS)
Measurement 2 (M_2):	Distance from the reference line to the center of resistance (CR) of the maxillary incisor
Measurement 3 (M_3):	Distance from the reference line to the incisal edge of the maxillary incisor
Measurement 4 (M_4):	Distance from the reference line to the incisal edge of the mandibular incisor
Measurement 5 (M_5):	Distance from the reference line to the center of resistance (CR) of the mandibular incisor
Measurement 6 (M_6):	Distance from the reference line to Menton (ME)

These six linear measurements yielded seven variables which were used to assess anterior vertical changes. These variables are described below (see Figures 2):

1. Maxilla (MXSK): Maxillary skeletal change was evaluated by change in M_1, distance from the reference line to ANS.

2. Upper Intrusion (BUI): Bodily movement of the upper incisor evaluates the amount of extrusion or intrusion by subtracting M_1 from M_2

3. Upper Tipping (TUI): Vertical change of the upper incisor due to tipping was evaluated by subtracting M_2 from M_3.

4. Lower Tipping (TLI): Tipping movements of the mandibular

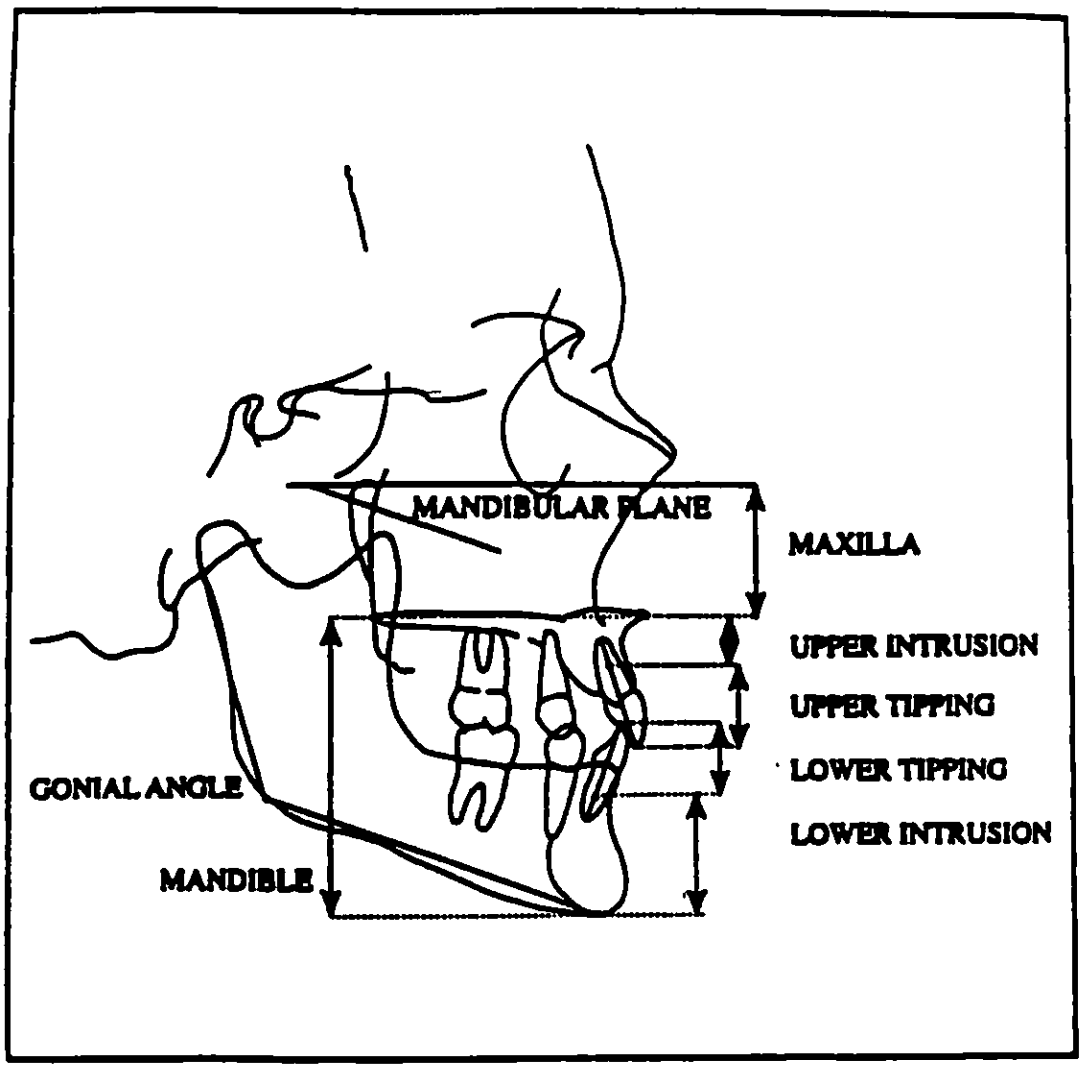


Figure 2. Cephalometric Tracing with Linear and Angular Variables

incisor was evaluated by subtracting M_4 from M_5.

5. Lower Intrusion (BLI): Bodily movement of the mandibular incisor was evaluated by subtractingM_5 from M_6.

6. Mandible (MNSK): Mandibular skeletal change was evaluated by subtracting M_1 from M_6.

7. Overbite (OB): Change in overbite was evaluated by subtracting M_4 from M_3.

It is important to note that the mandible (MNSK) measurement includes all factors which effect the displacement and vertical position of the mandible. By definition, molar extrusion accompanies increased mandibular skeletal change. Angular changes of the gonial and mandibular plane angles are also influencing factors. By measuring the difference in the angle formed by the intersection of the sella-nasion plane with the mandibular plane, the changes in the mandibular plane angle at T_1 (or C_1) and T_2 (or C_2) were compared. Furthermore, because Richardson (1969), and Moss and Salentijn (1971) claimed the shape of the mandible to be more important than the size in the deep overbite patients, the gonial angle was also measured (see Figure 2).

Convention of Signs

A positive sign was given to all dental and skeletal responses associated with vertical decrease of incisor overlap. A negative sign was given to those responses associated with vertical increase of overlap. In other words, dental and skeletal movements away from the occlusal plane were given a positive sign, while movements towards the occlusal plane

were given a negative sign (See Figure 3).

Variable: MXSK
+ = upward movement of anterior maxilla
- = downward movement of anterior maxilla

Variable: BUI
+ = upper incisor intrusion
- = upper incisor extrusion

Variable: TUI
+ = labial tipping of upper incisor
- = uprighting of upper incisor

Variable: TLI
+ = labial tipping of lower incisor
- = uprighting of lower incisor

Variable: BLI
+ = lower incisor intrusion
- = lower incisor extrusion

Variable: MNSK
+ = downward movement of anterior mandible
- = upward movement of anterior mandible

Variable: OB
+ = overbite decreased
- = overbite increased

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

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

Statistical Methods

The purpose of this study was to determine the relative contribution of various skeletal and dental components in deep overbite correction. By

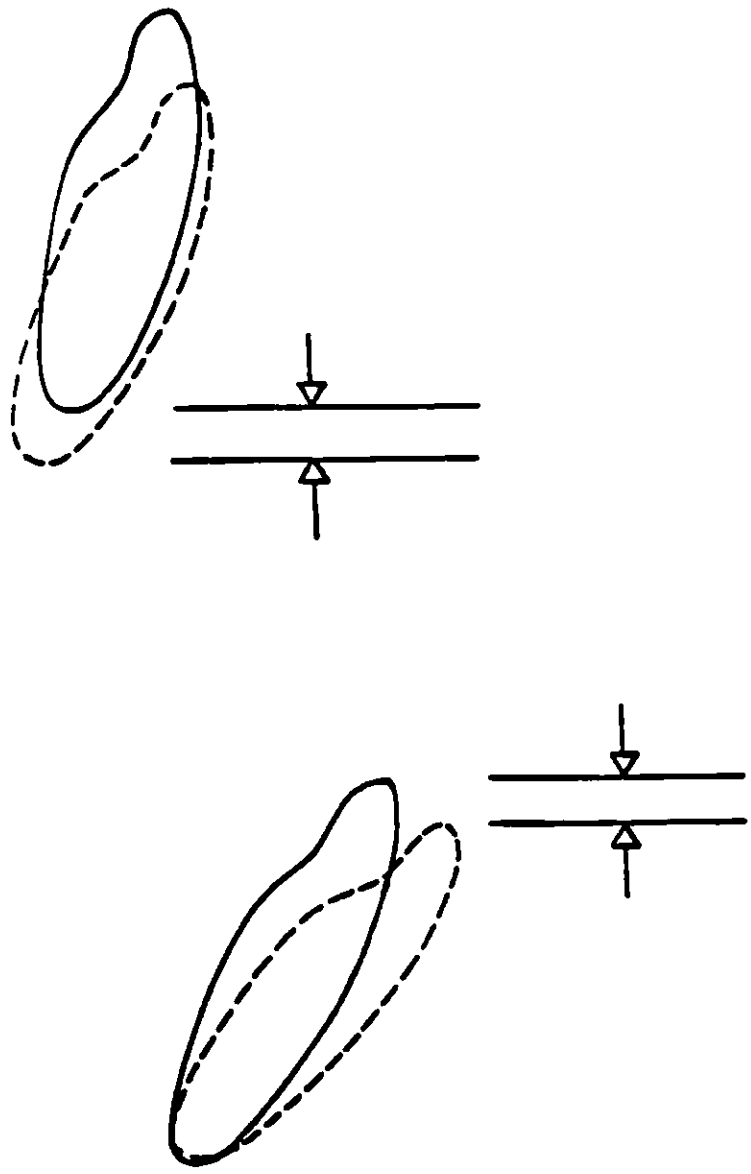


Figure 3. Comparing Bodily Versus Tipping Movements of Incisors for Deep Bite Correction.

careful design using a matched sample, changes due to normal growth can be factored out by subtracting the mean changes in the control group from the mean changes in the treated group. Thus, changes due to orthodontic treatment can be isolated.

Data analysis was performed utilizing the Statistical Package for the Social Sciences (SPSS/PC+) in the Orthodontic Department at Case Western Reserve University. Means, standard deviations, and standard error measurements for each of the seven linear and two angular measurements were determined. Delta values for the changes being analyzed were then calculated by subtracting the difference between T_1 (C_1) and T_2 (C_2). Means, standard deviations, and standard error measurements for the delta values were then determined. For the matched sample between group (T_1-T_2 vs C_1-C_2) differences were examined using paired t-tests. A p-value 0.05 was used to assign statistical significance. Due to sample size, the variables of male, female, and facial type were only compared using descriptive statistics.

Measurement Reliability

Since each lateral headfilm provided the basis for a carefully prepared tracing to be measured, considerable attention was given to maintaining a high degree of accuracy. Measurement error was examined by remeasuring the seven linear and two angular variables of ten randomly selected radiographs. The initial mean value and repeat mean value were

compared for each cephalometric variable using reliability coefficients. Tracing error was evaluated by retracing ten radiographs chosen at random by the investigator and the cephalometric analysis repeated on those tracings. The calculations were made for the linear and angular measurements. The initial and repeat means were then compared by applying reliability coefficients (r), to determine strength of relationship between the repeated tracings (Guilford 1971).

RESULTS

Sample Description

The control and treated groups consisted of thirty-one individuals presenting a deep overbite malocclusion, four first bicuspid extractions, and treated with Tweed mechanics. Each group contained a total of sixteen (51%) males and fifteen (49%) females (see Table 2). Twelve (38%) patients were leptoprosopic, thirteen (42%) patients were mesoprosopic, and six (20%) were euryprosopic in both groups. The mean age of the control and treated groups at time one was twelve years and eleven months. The average time interval between the beginning and the end of treatment for the control and treated groups was thirty-seven and thirty-eight months, respectively.

TABLE 2.--Comparison Between the Control and the Treated Groups

	CONTROL	TREATED
TOTAL SAMPLE	31	31
# of FEMALES	15	15
# of MALES	16	16
AGE: TIME 1	12yr 11mo	12yr 11mo
AGE: TIME 2	16yr 0mo	16yr 1mo
TIME 1 TO TIME 2	37 months	38 months

Due to this study design involving a matched sample with smaller subgroups, multiple t-tests will be avoided. Paired t-tests will be applied where appropriate. Descriptive statistics, including only the means and standard deviations of the control and treated groups, are listed for reference (see Table 3). All data appeared to be acceptable. Figures 4 and 5 graphically represent the contribution of the variables in deep overbite correction.

Control Verses Treated Group at Time 1

In this study, both treatment and control groups were selected and matched according to race (caucasian), age, sex, facial type, time interval, and deep overbite. There were two variables that had a significant difference ($p \leq 0.001$) when comparing the time one radiographs of both groups (see Table 4). The mean values for TLI were greater in the treated group than the control group; the lower incisors (16.4 mm) were more upright in relation to the horizontal reference line within the treated group.

The variable OB (overbite) was also significantly ($p \leq 0.001$) greater in the treated group than the control group. In the beginning, the treated group overbite was 1.0 mm deeper than was the control group.

At time one, there were no significant differences ($p \leq 0.05$) between the groups in the amount of vertical position occlusally of the upper and lower incisors in reference to anterior nasal spine and menton, the inclination of the upper incisors, the position of the maxilla and mandible, the gonial angle, or the mandibular plane angle.

TABLE 3.--Descriptive Statistics: Means and Standard Deviations of Time 1 and Time 2 for Control and Treated groups

	TREATED-T1		TREATED-T2		CONTROL-C1		CONTROL-C2	
VAR.	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD
MXSK	25.5	± 3.07	27.8	± 3.46	23.9	± 3.19	26.4	± 3.74
BUI	9.0	± 2.84	8.3	± 3.10	10.1	± 2.07	11.7	± 2.56
TUI	19.6	± 1.70	19.9	± 1.83	19.3	± 1.66	19.2	± 1.64
TLI	16.4	± 1.39	16.3	± 1.43	15.0	± 1.78	15.0	± 1.87
BLI	23.7	± 2.19	23.0	± 3.08	23.5	± 1.59	25.7	± 2.51
MNSK	61.7	± 5.36	65.4	± 5.55	62.1	± 3.30	65.6	± 4.40
OB	6.8	± 1.05	2.6	± 1.17	5.8	± 1.28	5.5	± 1.34
GO	122.6	± 5.69	120.7	± 5.89	122.4	± 5.92	120.3	± 5.66
MPA	32.6	± 5.60	31.5	± 6.15	31.4	± 4.22	30.2	± 4.81

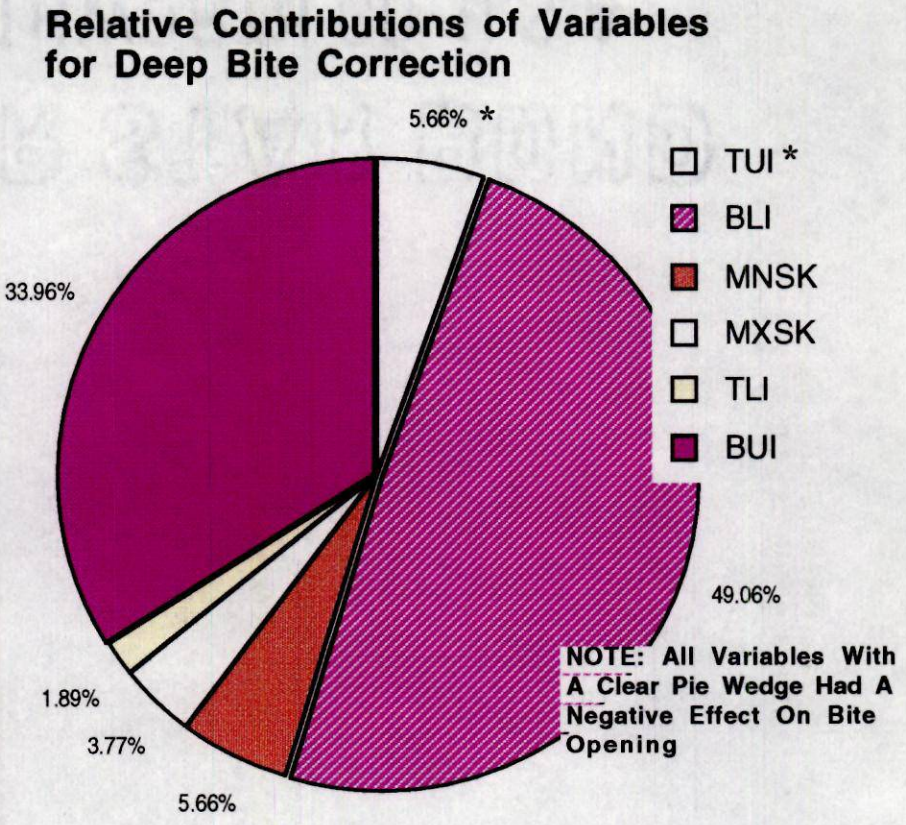


Figure 4: Contribution to deep bite correction. The majority of correction came from bodily intrusion of the incisors.

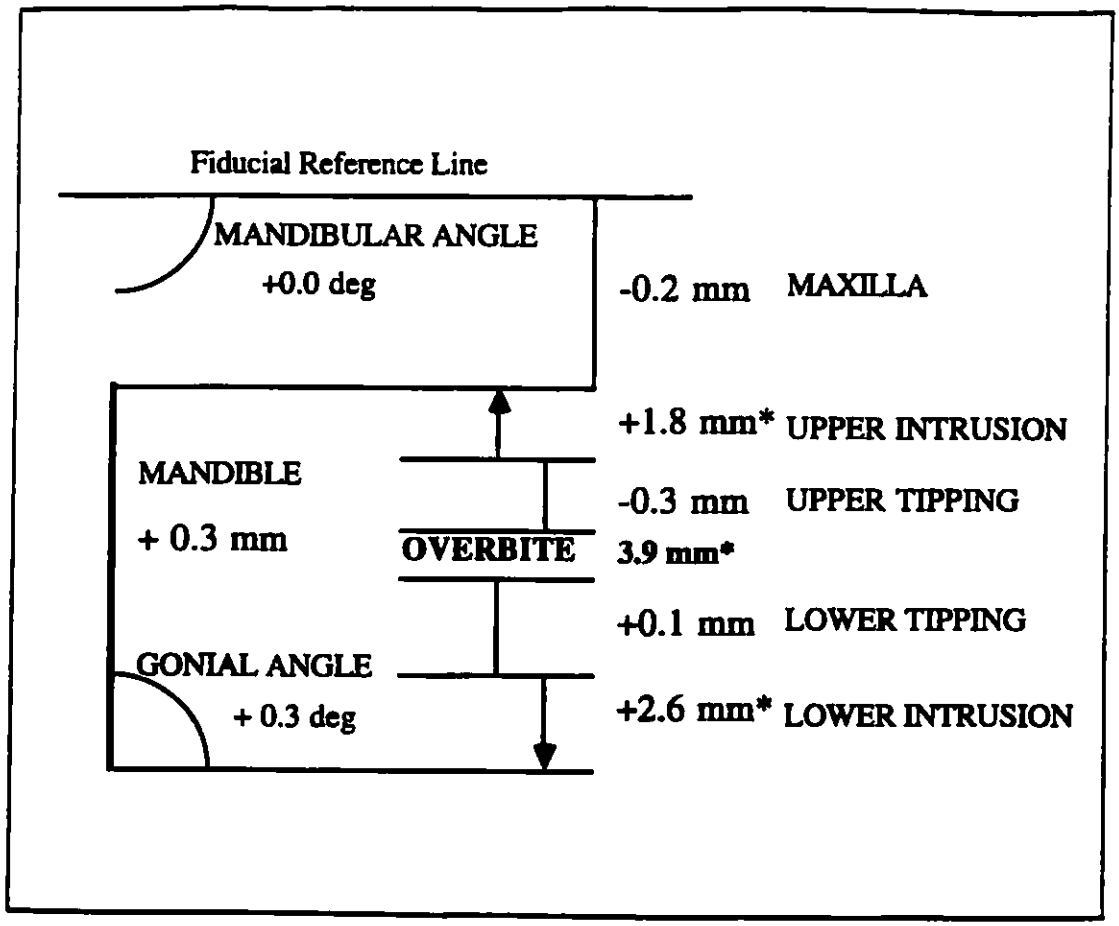


Figure 5: Relative contribution of Variables for Deep Overbite Correction.

TABLE 4.--Comparison Between the Control and Treated groups at Time 1

	CONTROL		TREATED			
VARIABLE	MEAN	STD	MEAN	STD	P-VALUE	SIG.
MXSK	3.9	± 3.19	25.5	± 3.07	0.058	
BUI	10.1	± 2.07	8.9	± 2.84	0.111	
TUI	19.3	± 1.65	19.6	± 1.70	0.461	
TLI	15.0	± 1.77	16.4	± 1.39	0.001	* * *
BLI	23.5	± 1.59	23.4	± 2.19	0.803	
MNSK	62.1	± 3.30	61.7	± 5.36	0.693	
OB	5.8	± 1.28	6.8	± 1.05	0.001	* * *
GO	122.4	± 5.92	122.5	± 5.68	0.898	
MPA	31.4	± 4.22	32.5	± 5.60	0.441	

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

The Control Group

The control group showed 0.3 mm bite opening during the thirty-seven months between time one and time two radiographs (see Table 5 and Figures 6-10). The mean values for variables MXSK, BUI, TLI, BLI, GO, and MPA all moved in a negative direction for opening the deep overbite. The mean values for the variables TUI and MNSK had a positive effect on opening of the deep overbite.

The Treated Group

The treated group showed 4.2 mm bite opening during the thirty-eight months between time one and time two radiographs (see Table 5 and Figures 6-10). The mean values for the variables MXSK, TUI, GO, and MPA all moved in a negative direction for opening the deep overbite. The mean values for the variables BUI, TLI, BLI, and MNSK had a positive effect on opening of the deep overbite.

Control Verses Treated Group From Time 1 to Time 2

The upper and lower incisors showed a highly significant ($p \leq 0.001$) amount of bodily intrusion (BUI and BLI) contributing to opening of the deep overbite. The combination of the variables BUI (0.2 mm) and BLI (0.72 mm) accounted for 4.4 mm more opening of the deep bite through bodily intrusion relative to the maxilla and mandible in the treated group (absolute intrusion) when compared to the control group (relative intrusion).

Although the variables TUI (-0.32 mm) and TLI (0.14 mm) failed to reach ($p \leq 0.05$) significance. When compared to the controls, they were

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

	CONTROL		TREATED			
VARIABLE	MEAN	STD	MEAN	STD	P-VALUE	SIG.
MXSK	-2.50	± 1.76	-2.30	± 1.84	0.626	NS
BUI	-1.60	± 1.11	+0.20	± 1.48	0.000	* * *
TUI	+0.05	± 0.29	-0.32	± 1.28	0.111	NS
TLI	-0.08	± 0.48	+0.14	± 0.99	0.259	NS
BLI	-1.90	± 1.55	+0.72	± 1.81	0.000	* * *
MNSK	+3.50	± 2.14	+3.80	± 2.39	0.581	NS
OB	+0.30	± 0.89	+4.20	± 1.15	0.000	* * *
GO	-2.10	± 1.61	-1.80	± 1.60	0.501	NS
MPA	-1.20	± 1.18	-1.20	± 1.57	0.785	NS

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

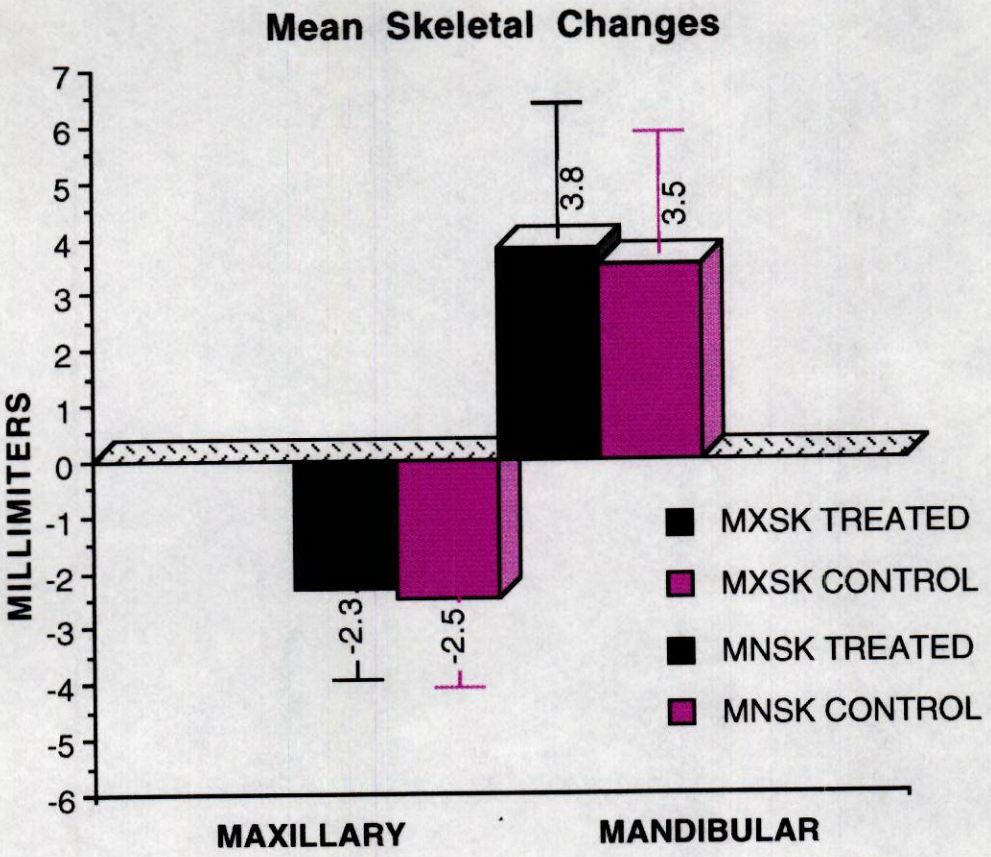


Figure 6. Mean changes for the maxilla and the mandible. The variable MXSK and MNSK showed no significant change between the Treated and the Control Groups

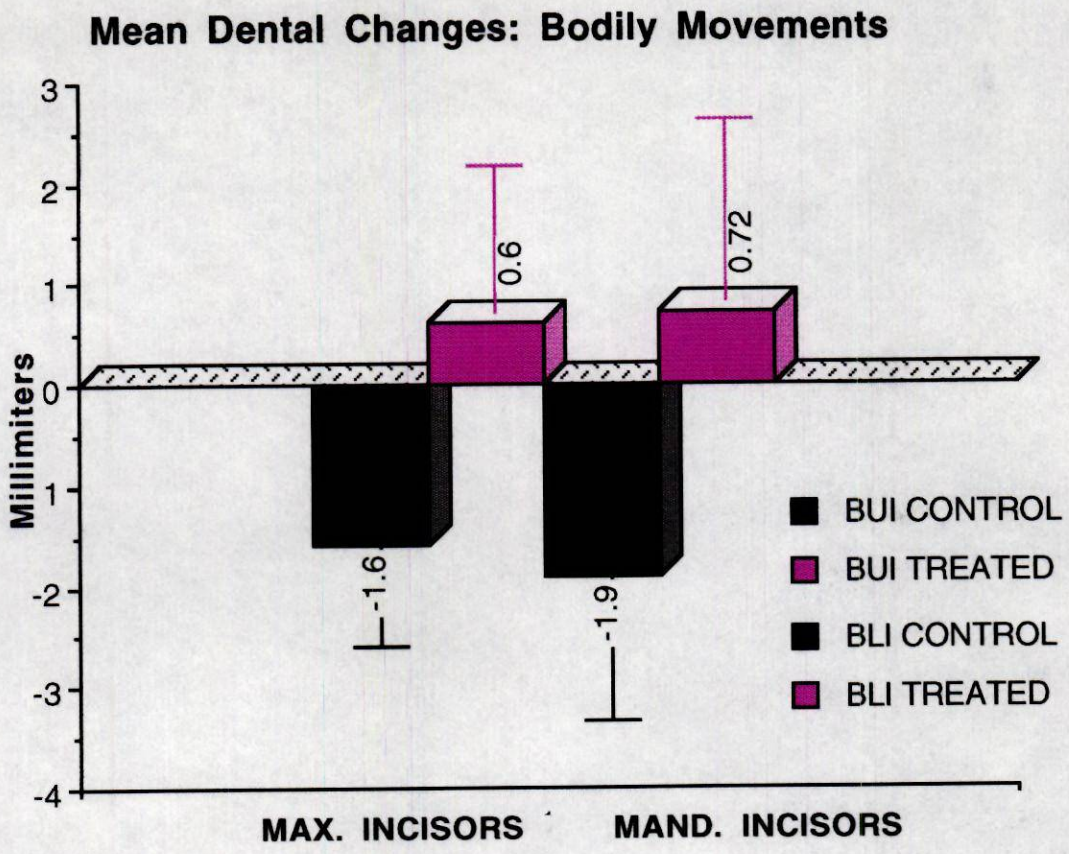


Figure 7. Bodily movements of the incisors. There was significant difference between the Treated and Control Grooups

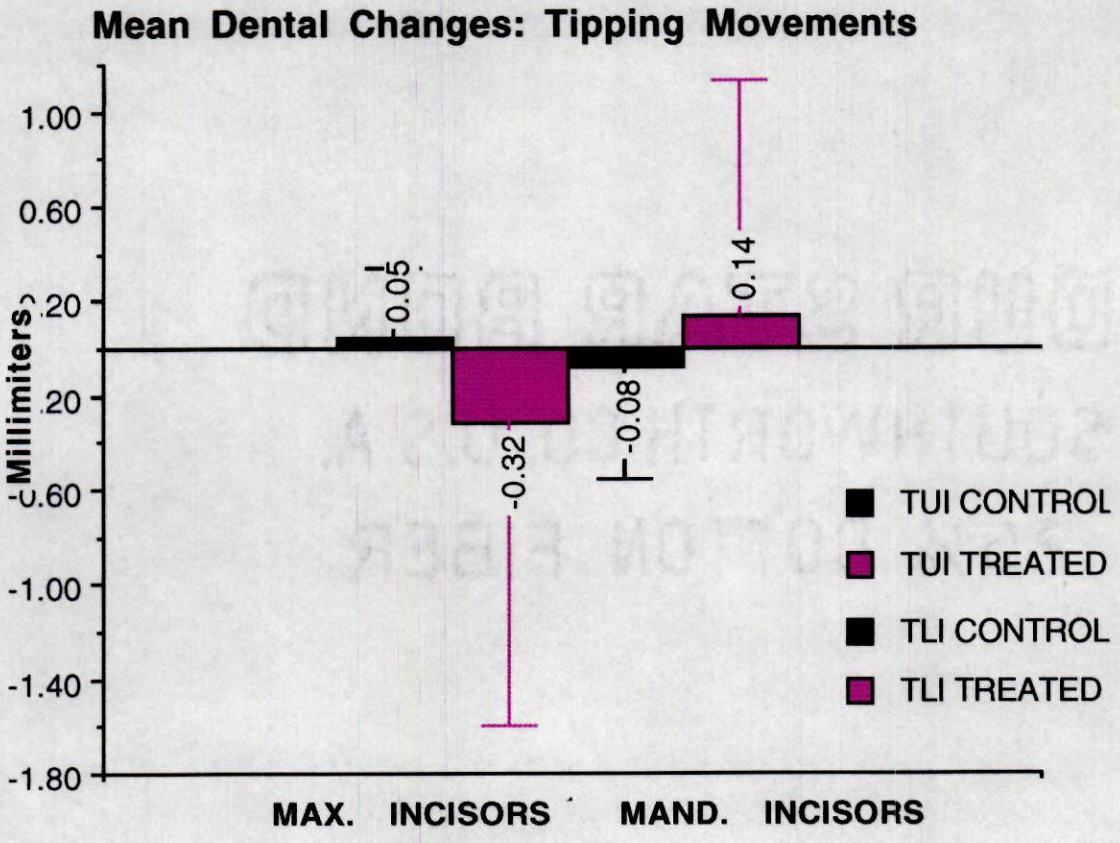


Figure 8. Tipping of the incisors. The Treated Group Showed more lingual tipping of the upper, and labial flaring of the lower incisors

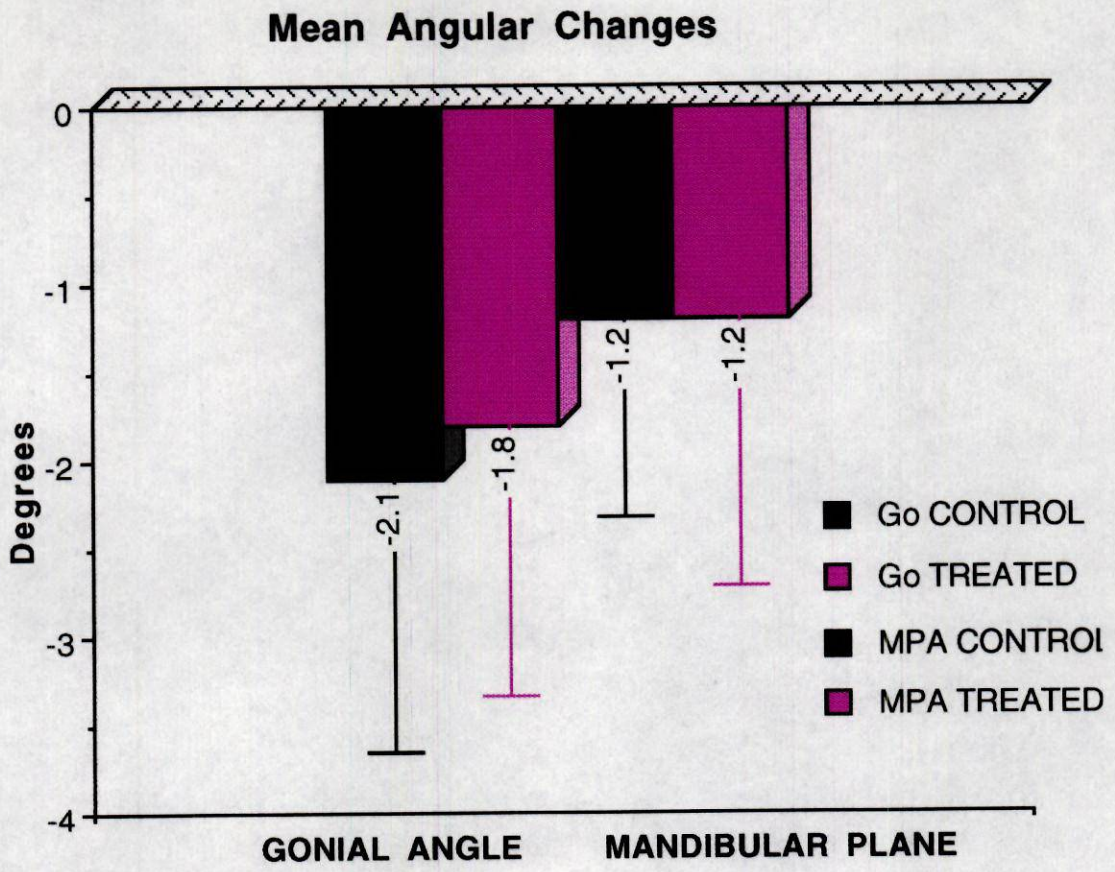


Figure 9. Mean changes for the Gonial and Mandibular Plane Angle showed closing

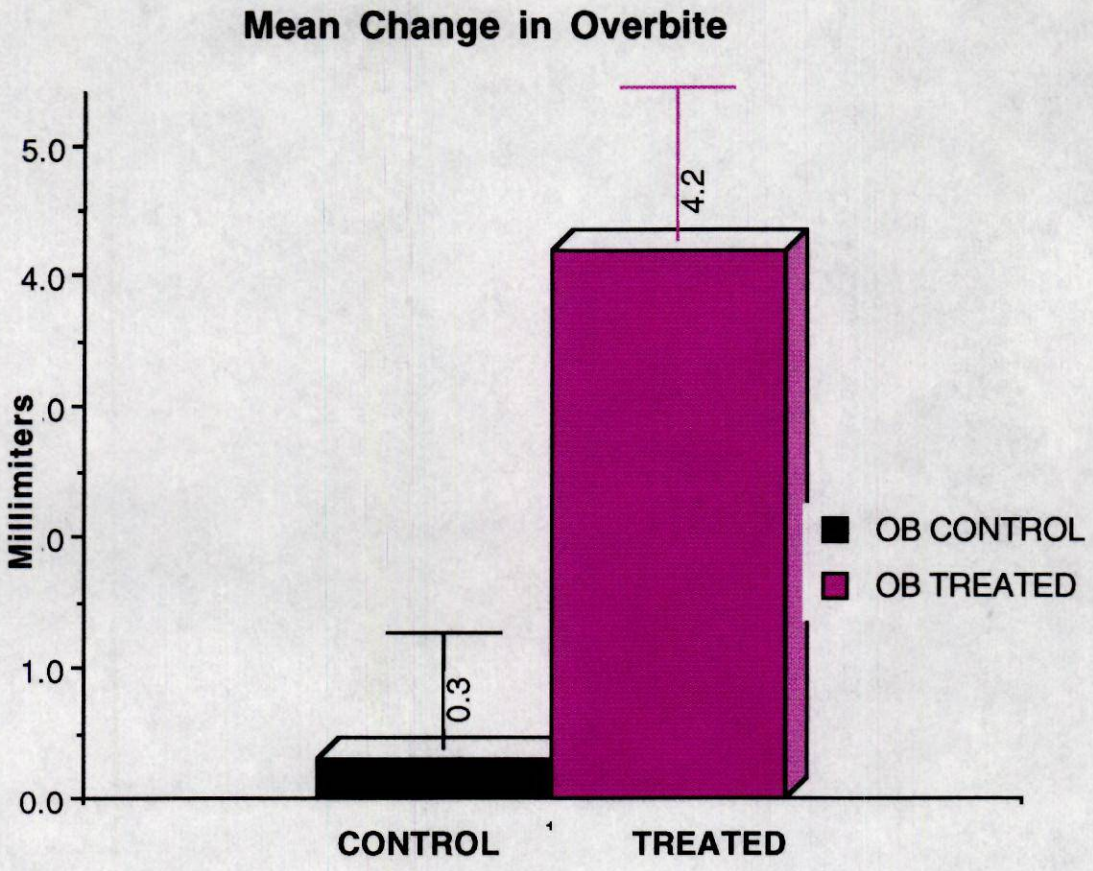


Figure 10. Overbite correction. The Treated Group had a significant decrease vertical incisor overbite than the Control Group

close enough to attribute 0.4 mm bite closure through maxillary incisor lingual tipping and 0.25 mm bite opening through flaring of the mandibular incisors. Overbite decreased significantly ($p \leq 0.001$) in the treated group. On average, the overbite was reduced nearly 4.0 mm when compared to the controls.

In comparing the overall changes between the control and the treated groups (see Table 5 and Figures 6-10), there were no significant differences between the mean values for the variables MXSK, TUI, TLI, MNSK GO, and MPA. Thirty-eight months of orthodontic treatment (Tweed mechanics, and posterior high pull head gear with J-hooks) with four first bicuspid extractions had no significant effect on the vertical position of the maxilla and mandible, the tipping movements of the upper and lower incisors, the gonial angle, or the mandibular plane angle.

Changes Within the Control Group by Sex

When comparing changes that occurred by sex, the male control (non-treated) group of patients showed a much greater increase in both the maxillary skeletal height (MXSK) and the mandibular skeletal height (MNSK) when compared to the females (see Table 6). Consistant with the skeletal movements, the males also showed a greater amount of bodily extrusion (vertical drift) of both the upper and lower incisors.

There was no obvious 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

TABLE 6.--Comparison of the Changes from Time 1 to Time 2 for the Control and Treated groups within Male and Female groups

	MALE					FEMALE				
	CONTROL		TREATED			CONTROL		TREATED		
Var.	Mean	Std.	Mean	Std.	P-vl.	Mean	Std	Mean	Std	P-vl.
MXSK	-3.6	1.66	–2.9	1.62	.409	–1.4	1.11	–1.6	1.86	.748
BUI	-2.1	1.05	-0.0	1.51	.000	–1.1	0.94	+0.4	1.47	.007
TUI	+0.1	0.38	–0.1	1.46	.702	-0.0	0.16	–0.6	1.03	.032
TLI	-0.3	0.39	–0.1	1.03	.371	+0.1	0.50	+0.3	0.95	.509
BLI	-2.5	1.57	+0.3	1.61	.000	–1.2	1.26	+1.2	1.93	.003
MnSK	+4.6	2.21	+4.6	2.33	.993	+2.4	1.38	+2.9	2.21	.410
OB	+0.2	0.84	+4.2	1.06	.000	+0.3	0.98	+4.1	1.27	.000
GO	–2.2	1.83	–2.1	1.77	.903	–2.1	1.41	–1.5	1.42	.294
MPA	–1.6	1.27	–1.6	1.70	.947	–0.8	0.96	–0.7	1.33	.722

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

When comparing the response differences of the treated group by sex, the males showed a greater amount of mandibular vertical and angular change, as well as maxillary vertical change than did the females (see Table 6). The female group showed a greater amount of absolute (factoring out growth) bodily intrusion of both the upper (BUI) and the lower (BLI) incisors. There was no profound difference between males and females within the treated group for the variables TUI, TLI, GO and OB.

Comparison of the Changes from Time 1 to Time 2 for the Control verses the Treated Groups within Male and Female Groups

Within the male group, the upper and lower incisors showed a highly significant ($p \leq 0.001$) amount of intrusion (BUI and BLI) to open the deep overbite (see Table 6). The combination of the variables BUI (0.0 mm) and BLI (0.3 mm) accounted for 4.3 mm bite opening through incisor intrusion in the treated group when compared to the control group (relative intrusion). Overbite was significantly ($p \leq 0.001$) opened 4.0 mm. When comparing the overall change between control and treated groups in males, there was no other significant difference between the mean values for the variables MXSK, TUI, TLI, MNSK, GO, and MPA.

As with the male group, in the females the upper and lower incisors also showed a highly significant ($p \leq 0.01$) amount of intrusion (BUI and BLI) (see Table 6). On average females have less growth effect but more absolute dental intrusion. The combination of variables BUI (0.4 mm) and BLI (1.2 mm) accounted for 3.9 mm of bite opening, very similar to the males

(4.3 mm) incisor intrusion but achieved differently. The amount of overbite correction was the same for females (4.1 mm) and males (4.2 mm). In the female group, no other significant differences were shown for the variables MXSK, TUI, TLI, MNSK, GO, and MPA.

Changes in the Control and Treated Groups by Facial Form

In the control group, the descriptive statistics showed very few obvious differences between the three facial types. All facial types had fairly homologous responses to normal growth for the variables examined (see Table 7). Although in the treated, as well as the control group, the MNSK increased generally as the face became more leptoprosopic. Overall, the upper and lower incisors in the treated group experienced increased intrusion absolutely and relatively when controlling for growth as faces became shorter and wider (euryprosopic).

Measurement Error

To assess investigator error, reliability coefficients were used. The larger the value of r, the more accurate the point was measured. If r value reaches one, it indicates a total correlation and measurements were exactly the same on both trials. Ten radiographs with tracings were randomly selected. Repeat measurement of M1-M6, MPA and GO were taken. Values for MXSK, BUI, TUI, OB, TLI, BLI, MNSK, GO, and MPA were then determined, and the two sets of means compared for each variable using the reliability coefficients (see Table 8). All reliability coefficients were between 94% and 99%, indicating low measurement error.

TABLE 7.--Descriptive Statistics: Means and Standard Deviations
Comparing Facial Type with Treatment (in mm)

		EURYPROSOPIC		MESOPROSOPIC		LEPTOPROSOPIC	
VAR.	Ct./Ex.	MEAN	STD	MEAN	STD	MEAN	STD
MXSK	Control	-2.9	0.88	-2.7	1.68	-2.2	2.18
	Exp.	-1.7	0.97	-2.1	1.46	-2.8	2.42
BUI	Control	-1.3	0.91	-1.6	1.16	-1.8	1.19
	Exp.	+1.2	1.21	+0.4	0.64	-0.5	1.90
TUI	Control	+0.0	0.38	+0.0	0.18	+0.1	0.35
	Exp.	-0.9	1.87	-0.3	1.12	-0.1	1.13
TLI	Control	-0.5	0.22	+0.0	0.48	+0.0	0.50
	Exp.	+0.6	0.63	-0.2	0.54	+0.3	1.37
BLI	Control	-1.9	0.93	-2.2	1.61	-1.6	1.76
	Exp.	+0.6	1.91	+1.0	1.51	+0.3	2.00
MNSK	Control	+3.3	1.22	+3.7	2.32	+3.4	2.42
	Exp.	+3.2	2.59	+3.8	1.91	+3.9	2.88
OB	Control	-0.2	0.58	+0.2	0.79	+0.7	1.02
	Exp.	+3.8	1.83	+4.5	0.91	+3.9	0.93
*GO	Control	-3.0	2.31	-1.8	1.63	-1.9	1.05
	Exp.	-1.2	1.12	-2.1	1.72	-1.8	1.69
*MPA	Control	-1.3	0.98	-1.0	1.08	-1.4	1.41
	Exp.	-0.7	0.51	-1.0	1.61	-1.5	1.86

* in degrees

Tracing Error

To assess intra-investigator tracing error, ten randomly selected radiographs were retraced and measured. The mean values from the second set of tracings for each variable were then compared to the first set of mean values using reliability coefficients (see Table 9). All reliability coefficients were between 96% and 99%, indicating minimal tracing error.

TABLE 8.--Describing Measurement Error

	MEASUREMENT 1		MEASUREMENT 2		
VARIABLE	MEAN	STD	MEAN	STD	RCOEF.
MXSK	-2.5	1.88	-2.5	1.93	.998
BUI	-1.4	2.81	-1.4	2.72	.997
TUI	-0.6	0.99	-0.6	1.00	.998
TLI	+0.2	0.48	+0.3	0.44	.996
BLI	+1.2	1.58	+1.1	1.79	.953
MNSK	+4.2	3.50	+4.2	3.84	.992
OB	+3.8	2.41	+3.8	2.92	.948
GO *	-1.7	1.91	-1.6	1.91	.977
MPA *	-1.3	1.87	-1.4	1.81	.965

(* in degrees)

TABLE 9.--Describing Tracing Error

VARIABLE	TRACING 1 MEAN	TRACING 1 STD	TRACING 2 MEAN	TRACING 2 STD	R COEF.
MXSK	-2.5	1.93	-2.8	1.78	.986
BUI	-1.4	2.72	-1.3	2.32	.988
TUI	-0.6	1.00	-0.8	0.95	.991
TLI	+0.3	1.24	+0.4	1.07	.952
BLI	+1.1	1.79	+1.3	2.04	.978
MNSK	+4.2	3.84	+4.4	3.78	.989
OB	+3.8	2.92	+3.7	2.97	.989
GO *	-1.6	1.91	-1.3	1.72	.982
MPA *	-1.4	1.81	-1.1	1.80	.970

(*in degees)

DISCUSSION

The purpose of the present study was quantitate the relative contributions of skeletal and dental components in the correction of deep overbite in extraction cases. Moreover, the study reports on the overall effect of extraction treatment using Tweed mechanics and the interaction with facial type and gender. The results revealed that deep overbite was corrected predominantly from absolute and relative intrusion of the upper and lower incisors while maintaining or slightly closing the mandibular plane angle, having a negative vertical effect but a positive sagital correction. Orthodontic treatment did not effect lower anterior facial height (MNSK). Figures 4 and 5 graphically represent the contribution of the variables in deep overbite correction. An arrow indicates the direction of change for all statistically significant between-group changes. Darker arrows represent a greater contribution. Movements contributing to a reduction in overbite were assigned a positive value. Movements which increased vertical overbite were assigned negative values. The following discussion will examine the general tendencies as well as the specific findings for each variable studied.

Vertical Skeletal Changes

In vertical and sagital orthodontic correction, control of the

nasomaxillary complex as well as the posterior teeth is important. In this study, all of the patients were treated with Tweed mechanics each involving anterior high-pull headgear (J-hook) (see Appendix I). Extraoral traction was used based on the empirical belief that J-hook headgear would maximize dental intrusion and prevent undesirable increases in facial height. Tweed mechanics involved the high-pull headgear (HPHG) with J-hooks to retract cuspids, intrude incisors, and hold the maxilla from its normal extent of downward growth.

The changes observed agree with those of Barton's (1972). Barton studied cases treated with four first premolar extractions with either anterior high-pull headgear (J-hook) or cervical traction. He found that the high-pull headgear allowed the chin to come further forward to assume the most favorable position while cervical traction tended to extrude the maxillary molars and cause the mandible to rotate further clockwise.

There was no significant difference between the control and the treated groups in comparing the mean changes for the maxillary skeletal change variable (MXSK) (see Figure 6). But a 0.2 mm difference from the control to the treated sample may demonstrate headgear benefit in a group where at least half may be more susceptible to increased vertical development and change. The most likely cause in bringing the maxilla further down than what the headgear might have allowed was the use of Class II elastics. Other factors such as patient compliance may have played a role.

Mandibular skeletal changes (MNSK) similarly showed non-significant differences between the control and treated groups, demonstrating no significant treatment effect. In observing the facial type subgroups, there was a tendency to see increases in MNSK with treatment as the faces became longer (more leptoprosopic). Furthermore, the result of MNSK not being a significant treatment effect has different implication. One is that the vertical dimension was controlled successfully by Tweed philosophy in the use of high-pull head gear (J-hook), minimal intermaxillary elastics only after space closure, and (12-2, 10-2) anchorage preparation in heavy continuous arch wires. If these technical methods and auxiliaries were not used, significant or adverse changes could have resulted in the growing patients. An alternative hypothesis is that MNSK may not have significantly changed if auxiliaries were used or not (Parker et al., 1995). Vertical control for MNSK may be inessential. Many clinicians believe that selective and isolated tooth movements can be orthodontically accomplished. Some recommend incisor intrusion and avoid molar extrusion (Ricketts 1960), others desire molar extrusion and disapprove of incisor intrusion (Shudy 1966). In reality, the final determinant could be growth and development in a specific facial pattern.

Along with normal growth, the MNSK in the study's vertical analysis is affected by other elements. These elements involve both vertical and anterior-posterior position of the maxillary and mandibular molars, the gonial angle, and the vertical growth of the maxilla and ramus.

There is disagreement concerning the effect of bicuspid extraction on molar position and the vertical dimension. Many propose that extraction allows the posterior teeth to come forward having a negative effect on deep overbite (Witzig 1987). Other reports do not support this view (Pearson 1986; Staggers 1990; Dougherty 1968; Cusimano 1993). These studies show that if bicuspids are extracted in cases with either low or high mandibular plane angles, there is a range of mandibular and maxillary molar extrusion from a minimum of zero to a maximum of 4 mm, with higher angle cases being more susceptible to increases in vertical dimension in growing patients. In comparison, reports on untreated groups by Creekmore (1967) and Ricketts (1960) show that lower molar height typically increases by an average of about 1.5 mm over a two year period. In addition, McNamara (1981) reported that the lower face height typically increases 1.0 mm per year in an untreated individual. This is proportionate with the molar height increase. In the present study results (see Table 5) there was no significant difference between the control and treated groups involving skeletal growth. The data agrees with the above reports on incrimental growth of the lower face. Over an average thirty-seven month treatment period the MNSK increased approximately 1.0 mm per year, implying there was no adverse treatment effect on dental and skeletal components.

It is logical to assume that extrusion of posterior teeth would have a positive effect on bite opening by increasing the vertical position of the mandible, while mesial movement of the buccal segments would have a

negative vertical effect by moving the termed wedge more anterior enabling for mandibular counterclockwise rotation and deepening of the bite.

In this study, four first bicuspids were probably extracted primarily to alleviate tooth/arch length discrepancies and reduce the procumbancy of the anterior teeth. During space closure some extraction space was consumed by relieving crowding and the remainder used to retract anterior teeth with some lost in the anchorage slipping forward (Pearson 1978). We must assume that at least some mesial movement of the buccal segments took place in the treated group, especially since approximately half of the sample was Class II dentally. This would require even more protraction of the molars to correct the molar relationship. Furthermore, most orthodontic mechanics are extrusive in nature, and as the molar segments move mesially, extrusion takes place and seems to maintain or increase the vertical dimension. This extrusion is demonstrated in many studies (Parker 1990; Kishiyama 1987; Hans 1994), although post-treatment relapse is not mentioned. Some claim that anchorage preparation and Class II elastics as used in Tweed mechanics extrudes posterior teeth (Staggers 1994). However, this study found no statistically significant difference in lower facial height between the control and treated groups. Even though the analysis used in the present study does not specifically measure molar position, it can be implied that minimal posterior extrusion took place because neither MNSK nor FMA increased with treatment.. This is further substantiated by the fact that the sample was fairly well distributed by facial type, not just

purely euryprosopic, low-angle cases that are less susceptible to vertical increase. The results tend to disagree with some of the literature (Dake and Sinclair 1989; Staggers 1990) claiming that posterior segments extrude predominantly.

Since there is minimal differences in the vertical position of the maxilla, the change in gonial angle, and the position of mandibular skeletal height, it can be implied that careful anchorage preparation, mid-buccal leveling of the arch, and control of the occlusal plane, along with high-pull headgear (J-hook) are effective in controlling vertical facial height. Although facial height increased with treatment the increase was the same as that seen in the untreated control group. The overall slight mandibular skeletal increase in the treatment sample could be attributed to minimal posterior extrusion and/or bone remodeling at the land mark menton. It can also be considered that more mesial and vertical movement of the molars might have been observed if second bicuspids, rather than first bicuspids, were extracted (Parker et al.,1995). However, molar extrusion decreases overbite but causes backward rotation of the mandible. Such rotation may be undesirable in a retrognathic profile.

Dental Changes

In this study the analysis specifically analyzed vertical changes, and allowed separation of bodily movements of the upper and lower incisors from tipping movements (see Figures 4, 5, 7, and 8). There was no significant difference in the amount of incisor tipping (TUI and TLI) between

the control and the treated groups. General findings, although, indicate that the maxillary incisors (TUI) tipped unfavorably, uprighting as they were retracted into the extraction site, having a negative (0.3 mm) effect on bite opening. The lower incisors (TLI) reacted in the opposite direction by flaring, which can be anticipated with the use of Class II elastics. As the axial inclination of the lower incisor becomes more proclined the vertical component becomes smaller, thus having a positive effect on bite opening. In Tweed mechanics, the incisors are retracted in a controlled fashion using large stainless steel retraction arches (0.021" x 0.025") with anterior lingual root torque to control the incisors. These results agree with Dake and Sinclair (1989) and Parker et al., (1995) who showed flaring of the lower incisors in bioprogressive treatment and Tweed mechanics. However, Tweed mechanics showed much less flaring, possibly due to control of the occlusal plane with heavy archwires.

In the treated group there was significantly ($p \leq 0.001$) more bodily intrusion of the upper and lower incisors as compared to the control group (see Figures 7 and 8). The combination of the variables BUI (0.2 mm) and BLI (0.72 mm) accounted for 4.4 mm more anterior bite opening through incisor intrusion. This includes the amount of relative intrusion, or holding against normal growth. As shown graphically (see Figure 5), almost 100% of overbite correction is from absolute and/or growth related relative intrusion (upper intrusion = 1.8 mm + lower intrusion = 2.6 mm/overbite = 3.9 mm).

The Tweed philosophy of treatment puts a premium on incisor intrusion to open deep bites while controlling vertical facial height. The results of this study are congruent with Tweed's objectives. Bodily intrusion of the upper incisors is believed by many to be a basic and essential component to overbite correction (Merrifield 1970, Burstone 1977). Intrusion of the lower anteriors to correct deep overbite has also been advocated by many clinicians (Ricketts 1979, Burstone 1977). The Tweed mechanics in the present study were successful and most of the correction was due to bodily intrusion. Interestingly, even though the technique's intent is not to specifically intrude lower anteriors, these teeth also contributed almost half of the affective treatment change.

An orthodontist is often faced with extraction treatment due to arch length deficiency, or a Class II dental and/or skeletal relationship. It is the orthodontist's job to create an environment that allows for full expression of growth. This study demonstrates that Tweed mechanics employed by orthodontic residents at Case Western Reserve maintained the occlusal plane overall and controlled the maxillary and mandibular molars, as well as the anterior vertical dimension. Although some may argue that these goals do not always optimize facial esthetics the data indicates that vertical facial height is effectively controlled with Tweed mechanics and dental extraction.

Angular Changes

As presented in the materials and method section, this study used the angular measurement Sella-Nasion/Mandibular Plane (SNMP) for the

mandibular plane angle. This measurement technique was used in Dietrich's (1992) study and adopted here to maintain consistency for future comparison. It was selected because of the greater accuracy in locating Sella-Nasion as compared to the Frankfort Horizontal Plane. Proffit (1986) stated that on average, the SNMP is seven degrees greater than the Frankfort Horizontal/Mandibular Plane angle.

In review of the pre-treatment radiographs of the control (31.4°) and treated (32.5°) groups, there was no significant difference in the measurement for SN-Mandibular Plane. These measurements represent a sample containing approximately 33% of each facial type with deep overbite malocclusions.

When comparing the overall changes between the control group and the treated group, there was no significant difference between the mean value for the variable MPA (see Figure 9). Both the control and treated groups showed a slight decrease (-1.2°), or closing of the mandibular plane, during the same thirty-eight month interval. These results support McNamara's (1986) claim that in an adolescent patient with normal growth and development, the mandibular plane angle is expected to decrease about one degree every three years. Furthermore, the results of the treated group demonstrate that extraction treatment involving Tweed mechanics tends to maintain the mandibular plane angle, and the vertical height of both the maxilla (MXSK) and the mandible (MNSK). This would suggest that patients with increased lower facial height and mandibular retrognathia

would gain greatest esthetic benefit from this technique. These orthodontic mechanics allow for favorable growth to take place if the potential exists, allowing forward rotation of the mandible. The overbite correction is then treated with absolute and relative intrusion of the anterior segments for a stable result.

Along with the MPA, the gonial angle (GO) of both control and treated groups showed closing over time with no significant difference (see Figure 9). Nanda (1990) found a progressive reduction in angles in deep bite cases showing an increase in overbite. This change was credited to the decrease in Frankfort Mandibular Angle (FMA) and Gonial Angle (GO) with age. The findings of this study are also consistent with Richardson's (1969) findings showing decreases in the gonial angle with age. From the initial radiographs in this study there was no significant difference in the measurement of the gonial angle between the control (122.5°) and the treated (122.5°) groups. The mean gonial angles of both groups fell exactly on the normal cephalometric value for gonial angle (123.0°). Overall, the contribution of the variable GO had a negative effect on overbite.

Overbite Correction

The amount of vertical overbite is extremely variable and is one of the most common and early manifestations of a malocclusion (Goldstein 1936). In this study, excessive overbite was treated to ideal or beyond to account for relapse of the dentition. Dietrich (1992), in the study of open bite malocclusion, used Rickett's (1982) ideal value of 2.5 mm, a minimum value

used as the basis for comparison. The same will be used in the present study of deep overbite correction. In the treated sample at the post-treatment (T_2) 88% of the patients, twenty-seven of thirty-one, had a minimum overbite correction of 3.6 mm. Overall, the treated group had a significant decrease in vertical incisor overlap (3.9 mm) compared to the control group (see Figure 10). It was also conclusive that in the control group the overbite slighty decreased over time, supporting Bjork's (1953) theory.

In the vertical analysis used, comment should be made on the propensity to over-estimate the incisor overbite relationship. All linear measurements were made relative to a constructed horizontal reference line (see Figure 2) which closely parallels the Frankfort Horizontal plane. Although clinicians more often use the occlusal plane as a reference line to measure overbite it was the design of this study to use the Frankfort Horizontal plane and still maintain clinical usefulness and relevance.

Due to the fact that the average horizontal plane and the occlusal plane diverge anteriorly eight to fourteen degrees, the measurements used in this investigation could slightly differ from those made from the occlusal plane. Dietrich (1992) has illustrated the difference between the two measurements nicely.

Closely related to overbite correction is the issue of overbite relapse. For the growing patient with deep overbite and decreased lower facial height, the orthodontist may desire to increase facial height with treatment to

improve facial esthetics. Although as facial height increases, stability may decrease due to the muscle environment. If there is change due to treatment in the functional equilibrium of the different structural components, there may be varying degrees of adaptive growth to allow for stable increases in facial height. It was not the intent of this investigation to evaluate relapse but according to a classic ten year post-retention study (Simons and Joondeph 1973), the present deep overbite sample treated with four first bicuspid extractions and Tweed mechanics (high-pull headgear, J-hook) should stand the test of time. Even though some natural post-retention relapse will take place in the deep overbite sample, there was minimal incisor protrusion of the upper and lower incisors during treatment. The tipping of the occlusal plane was avoided by careful vertical control of the anterior and posterior segments. These factors are inherent to the Tweed technique and are supported by the conclusions made by Simons and Joondeph (1973) in favor of long term stability. In addition, Simons and Joondeph claimed post-retention change in overbite was not related to whether or not permanent teeth were extracted during orthodontic treatment.

Comparison Between Males and Females

Both the treatment and control samples had sixteen males and fifteen females and the average age at the start of treatment was twelve years, eleven months. Sample selection criteria was based on adolescents chosen before the end of active pubertal growth, which was before about fourteen years of age in females and sixteen to eighteen years in males.

With an average start date of twelve years, eleven months, the males within the control group showed over 50% increase in both the maxillary skeletal height (MXSK) and the mandibular skeletal height (MNSK) (see Table 6). This was anticipated since the males had more significant growth years remaining at the start of treatment. The males in the treated group also showed twice as much maxillary (MXSK) and mandibular (MNSK) skeletal change than the females (see Table 6).

The males in the treated group showed a greater amount of relative bodily intrusion of both the upper (BUI) and the lower (BLI) incisors than the treated females. In contrast, the female treated group showed a greater amount of absolute bodily intrusion of the incisors during treatment.

Within the male treated group, the combination of the variables BUI (0.0 mm) and BLI (0.3 mm) accounted for 4.3 mm of bite opening when compared to the control group. Approximately 90% of intrusion was relative to growth. Whereas in the female treated group, the combined variables BUI (0.4 mm) and BLI (1.2 mm) accounted for 3.9 mm of bite opening, approximately the same or slightly less than the males. In the female group, 50% of bite opening was due to relative intrusion and 50% due to absolute intrusion. This is evidence that the females were beyond the peak growth velocity and towards the end of the growth duration. It is shown that approximately 90% of the change in overbite in the male group and 50% change in overbite in the female group was directly related to changes in vertical growth of the face. It is generally believed that female patients are

more cooperative with treatment. This is probably good because to achieve the same result as males more dental movement is necessary for females. However, while including the amount of relative intrusion, or holding against growth, the overbite correction observed for males and females was similar.

The Effect on Facial Type

The sample size of thirty-one subjects was also divided into three subgroups based on facial type: euryprosopic (7), mesoprosopic (12), and leptoprosopic (12). Controls subjects were also matched according to facial pattern. Due to the small subgroup size and the possibility of an abnormal distribution, only descriptive statistics will be examined and general comments made in hopes to understand how facial type influences deep overbite correction.

Significant correction of overbite was achieved in all facial types. All groups showed a similar amount of overbite reduction (see Table 7). The most interesting observations involve the variables BUI, BLI, MNSK and the angular variables GO and MPA.

Overall, the variables MXSK, TUI, and TLI were found to be constant within each facial type as fairly unfavorable responses. As for bodily intrusion of the upper and lower incisors, there was a tendency for more intrusion as the face became shorter. There are two implications in this trend. One is that symphyseal morphology in long facial patterns are more narrow, limiting the amount of incisor intrusion (Ricketts 1964). The other implication is that muscular forces in patients with shorter faces and lower

mandibular plane angles etc., tend to depress the posterior segment reducing the possibility of posterior extrusion and directing most of the force to the anteriors where it is expressed as incisor intrusion. The importance of the musculature and facial type is supported by many clinicians (Engle 1980; Burstone 1977; Sassouni and Nanda 1964). In general, as the face becomes more euryprosopic, lower incisor intrusion is increased. This premise is not in accord with Otto (1980) who found that the patient's facial type had no significant impact upon the amount of intrusion seen.

As for the mandibular skeletal change (MNSK), there was a tendency to see increases with treatment as well as in the controls as the face became longer. This supports Creekmore (1967) who found that shorter faces were less susceptible to vertical increases. It then follows that longer faces are more susceptible to molar extrusion. In observing the angular changes, the mandibular plane angel (MPA) and the gonial angle (GO) were controlled or decreased in all facial types.

Matching the Samples

When comparing the start records, or time one radiographs of the matched treatment and control groups, there were only two variables that were significantly different ($p \leq 0.001$) at the start of treatment. The variables involved were tipping of the lower incisors (TLI) and overbite (OB). The mean value for TLI was greater in the treated group than the control group, i.e. the lower incisors (16.4 mm) were more upright in relation to the horizontal reference line in the treated group. Even so, there was no

significant difference in change at time two.

The variable OB was also significantly ($p \leq 0.01$) more in the treated group than in the control group. In the beginning, the treated group overbite was 1.0 mm deeper than was the control, thus the data may underestimate the total treatment effect. Overall, the control and treated groups were matched as close as possible on the linear and angular measurements as well as the initial sample selection criteria.

Former Studies

As in a previous comparison of studies by Dietrich (1992), the present investigation has made comparisons between the current mean changes for the control group and the control groups in Parker's (1990) and Dietrich's (1992) in the study of deep overbite and openbite correction, respectively (see Table 10). All three studies employed the same vertical analysis, and shared similar time intervals between time one and time two radiographs (thirty-eight, thirty-eight, and forty months). The three studies examined different sample types. The current study selected thirty-one deep overbite malocclusions in all three facial types, as did Parker's sample of forty-five subjects. Dietrich's study consisted of thirty-one high angle open bite patients. As an overall whole the three control groups, inspite of their morphologic differences, were very much alike in dental and skeletal changes.The only slight differences between the three studies were in the variables TUI, OB, BLI, and MNSK. In the openbite group, the upper incisors tipped slightly labially (TUI) while in both deep bite groups the incisors were

TABLE 10.--Comparison between tne changes from Time 1 to Time 2 for the Control Groups in the current investigation, Parker's 1990 study and Dietrich's 1992 study

	PARKER 1990	DIETRICH 1992	DAMON 1995
VARIABLE	CONTROL MEAN VALUES	CONTROL MEAN VALUES	CONTROL MEAN VALUES
MXSK	2.5	2.4	2.5
BUI	1.2	1.1	1.6
TUI	0.3	0.2	0.1
TLI	-0.2	-0.3	-0.1
BLI	-2.6	-2.1	-1.9
MNSK	3.8	2.7	3.5
OB	-0.4	0.6	0.3
GO	1.7	1.6	2.1
MPA	0.8	0.8	1.2
Age Range :	11y 2m-14y 4m (38 months)	12y 10m-16y 2m (40 months)	12y 11m-16y0m (38 months)

found to tip lingually to a small degree. The lower incisor bodily extrusion (BLI) was similar between the present study and the open bite sample, but 0.7 mm less than the other deep bite sample. This could be attributed to the treatment time being slightly earlier. As for both the deep overbite control groups, they showed almost 25% - 30% more vertical mandibular growth (MNSK) than the open bite control group. This is not expected in the growth patterns of opposite malocclusions and facial types, even though 30% of the deep bite sample are leptoprosopic types. Neither can the difference be justified by initial age or age range since both the present study and the open bite study have exact average initial ages in the control samples. Comparing over bite (OB), Dietrich's and Parker's samples showed a slight increase while in the present study, OB showed a small decrese. Although these changes were in opposite directions in relation to the occlusal plane, there was only a difference of 0.7 mm between them.

The variables MXSK, BUI, TLI, GO, and MPA all moved in the same direction and were within 0.5 mm or degrees of each other. The maxillary skeletal height increased the same in all three groups as the upper (BUI) incisors extruded bodily and the lower (TLI) incisors tipped lingually towards the occlusal plane. All groups showed similar decreases in the mandibular plane angle (MPA) and the gonial angle (GO).

Error and Limitations

As shown in the results, there is a very low level of tracing and measurement error associated with the vertical analysis employed in this

study. Evidence is given by all reliability coefficients ranging between 95% and 99%. The vertical cephalometric analysis used in this study has been proven to be clinically relevant and useful in locating and measuring vertical changes in the dental and skeletal components of the face. With its easy and reliable accuracy and clinical significance, it can be of aid to the clinician as well as the researcher.

The results presented in this cephalometric study can be exposed to some limitations as in all research of this type. First, the standardization of the lateral cephalograms was not applied. This could be a source of measurement error due to the different unadjusted cephalometric magnifications. Although, it is beneficial that all well-defined lateral cephalograms selected were taken in the orthodontic department at Case Western Reserve University. Second, subdividing the sample into facial types may have reduced the sample size under the level needed to detect significant differences related to facial type. Third, the sample was treated by University residents not expert Tweed clinicians. The true orthodontic Tweed effect may not be fully appreciated. Instead, the operator was randomized by using only residents to eliminate any experimental bias. Fourth, although the measurements to menton could be confounded by mandibular rotation influencing overbite, regional superimpositions on the maxilla and mandible were applied and an average horizontal reference line constructed to discriminate between skeletal rotations and dental tipping in the assessment of treatment effects.

SUMMARY AND CONCLUSIONS

The intention of this study was to evaluate quantitatively the relative contribution of various skeletal and dental components in the orthodontic correction of the deep overbite malocclusion in the growing patient. The interaction of four first bicuspid extraction treatment with facial type and gender was also examined. A random sample of thirty-one patients was selected from among the completed cases of the Department of Orthodontics at Case Western Reserve University (CWRU). The treatment sample was selected on the basis of initial excessive overbite where the mandibular incisor was beyond the cingulum of the maxillary incisor. All patients were treated with four first bicuspid extractions and fixed edgewise appliances (Tweed Mechanics). The group was stratified according to facial type, age, and sex. Pre-treatment (T_1), and post-treatment (T_2) cephalometric radiographs were traced and measured.

The control group consisted of thirty-one untreated deep overbite patients selected from the Bolton Study, CWRU, Cleveland, Ohio. The controls were matched with the treated group according to facial type, age, sex, and treatment time, thus allowing growth and treatment effects to be separated out.

To determine treatment effect (and to quantify the exact nature of

tooth movement and skeletal change) a vertical cephalometric analysis (Hans et al., 1994; Parker 1990) was used. This analysis utilized six linear measurements and two angular measurements to isolate vertical changes in overbite. The six variables include maxillary skeletal change, tipping of the upper incisors, bodily movement of the upper incisors, mandibular skeletal change, lower incisors tipping, and bodily movement of the lower incisors.

The following observations were made:

1. Most of the deep overbite correction was accomplished by bodily intrusion of the upper and lower incisors.

2. Tweed mechanics with high-pull headgear (J-hook) are very effective in controlling the vertical in all three facial types.

3. Applying the Tweed technique controls the occlusal plane from rotating forward and over extruding the posterior.

4. Anchorage preparation and space closure before Class II elastics does not seem to be overly extrusive in nature.

5. Significant improvement of overbite was obtained in all thirty-one cases, an average of 3.9 mm.

6. Both of the control and treated groups showed equal closure of the mandibular plane angle and the gonial angle,implying the mechanics used in extraction site space closure maintained or slightly closed the MPA, allowing for the greatest sagital correct when needed.

7. With incrimental growth, the deep overbite slightly improves as the gonial and mandibular plane angle decrease.

8. Treatment did not increase anterior face height.

9. Male subjects demonstrated 4.3 mm of relative incisor intrusion (BUI = 2.1 mm and BLI = 2.2 mm) indicating that incisors were effectively held in position while

growth of the maxilla and mandible continued. Female subjects demonstrated 3.9 mm of absolute incisor intrusion (BUI = 1.5 mm and BLI = 2.4 mm) indicating that in the absense of growth teeth can still be intruded to achieve overbite correction.

10. Although overbite correction was achieved in all facial types, there was a tendency for more incisor intrusion as the face became shorter.

APPENDIX I
Summary of Treatment Sample

Pt. #	Sex	facial	Age St	Age DB	Extract	SN-MP	Tech	HPHG	El Cl II	El Cl III
1	M	L	11y 3m	15y 1m	Y	37	T	3mo		
2	M	L	16y 0m	19y 10m	Y	29.5	T		9mo	
3	M	E	11y 0m	13y 9m	Y	36	T	11mo		
4	M	M	10y 5m	12y 11m	Y	28.5	T	13mo	16mo	
5	M	M	12y 6m	15y 2m	Y	32.5	T	7mo	4mo	
6	M	M	14y 3m	17y 10m	Y	35	T	23mo	6mo	
7	M	L	12y 5m	16y 7m	Y	31	T	23mo	15mo	
8	M	L	13y 2m	19y 6m	Y	27.5	T	22mo	28mo	
9	M	M	14y 4m	16y 11m	Y	32	T	12mo	10mo	
10	M	M	12y 2m	14y 10m	Y	29	T	14mo	10mo	
11	M	M	13y 11m	16y 6m	Y	26.5	T	4mo		4mo
12	M	L	12y 10m	16y 5m	Y	33	T	22mo	25mo	
13	M	L	13y 6m	16y 0m	Y	40	T	10mo	14mo	
14	M	E	13y 8m	15y 10m	Y	21	T	10mo	15mo	
15	M	E	14y 2m	16y 2m	Y	28	T	10mo	10mo	
16	M	L	13y 4m	15y 2m	Y	35.5	T	15mo	8mo	
17	F	M	13y 6m	16y 3m	Y	28.5	T	5mo	2mo	
18	F	L	11y 11m	17y 7m	Y	41	T	5mo	12mo	4mo
19	F	E	11y 5m	14y 2m	Y	24	T	24mo	13mo	
20	F	E	13y 3m	15y 11m	Y	26.5	T	7mo	17mo	
21	F	L	13y 4m	16y 0m	Y	35	T	10mo	15mo	
22	F	M	11y 7m	14y 1m	Y	37	T	25mo	11mo	
23	F	L	14y 3m	16y 7m	Y	40	T	12mo	9mo	
24	F	M	14y 3m	17y 4m	Y	32	T	15mo	12mo	
25	F	M	13y 2m	15y 7m	Y	37	T	4mo		
26	F	L	10y 7m	12y 5m	Y	36	T	10mo	5mo	
27	F	E	14y 6m	18y 10m	Y	24	T		2mo	
28	F	L	13y 0m	15y 9m	Y	34	T	19mo		10mo
29	F	M	12y 11m	16y 4m	Y	35.5	T	15mo	20mo	
30	F	M	13y 2m	16y 7m	Y	30	T	18mo	12mo	
31	F	M	14y 5m	17y 3m	Y	46	T	8mo	15mo	

HPHG = High pull head gear with J-hooks (Auxillary in moths)
T = Tweed tecnique
E = Europrosopic
M = Mesoprosopic
L = leptoprosopic
SN-MP= Sella - Nasion Mandibular Plane Angle
Extract = Extraction of Four first bicuspid

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