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AN EVALUATION OF RESPONSE TO ORTHODONTIC TREATMENT OF DEEP OVERBITE IN EURY-, MESO-, AND LEPTOPROSOPIC INDIVIDUALS

by

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Submitted in partial fulfillment of the requirements

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Department of Orthodontics

CASE WESTERN RESERVE UNIVERSITY

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AN EVALUATION OF RESPONSE TO ORTHODONTIC TREATMENT OF DEEP OVERBITE IN EURY-, MESO-, AND LEPTOPROSOPIC INDIVIDUALS

Abstract

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The purpose of this study was to determine the effect of facial type on treatment response when orthodontically correcting an excessive overbite. The treated sample consisted of 94 patients who had an initial excessive overbite where the mandibular incisor was beyond the cingulum of the maxillary incisor. This was determined cephalometrically, however, if any questions remained, pre-treatment models were examined also. The second requirement was the availability of adequate pre-treatment and deband headfilms. Sample selection was not based on the orthodontic result since the outcome could then be biased. The control group consisted of 92 patients who met the same criteria of a deep overbite and adequate cephalograms. Both treated and control groups were divided into different facial types (eury-, meso-, and leptoprosopic) using the anthropometric classification of facial indices by Montague (1960). Because of a smaller number of euryprosopic facial types in the control group, a matched sample could not be achieved. The treated and control groups were statistically evaluated comparing mean ages. The control group was thus homogeneous with respect to having a deep bite, similar facial type, and similar mean ages. After digitization of the

tracings and statistical analyses of the data, the following observations were made:

1. Extreme facial types are not always oppositely affected by treatment, nor are they completely opposite in growth.

2. Bodily movement of the maxillary incisors does not seem to be limited by growth.

3. Bodily movement of the mandibular incisor and anterior mandibular skeletal change does appear to be related to facial type. Treatment effects mirrored growth changes on these parameters.

4. Headgear appears to be an important auxillary in treating deep overbite. It altered changes in MXSK that normally occurred in growth. Headgear may be the reason why no significant treatment effect was seen in MNSK in leptoprosopic individuals.

5. Tip of the maxillary incisor was consistently an unfavorable variable and was similar in proportion to the overall changes seen among facial types. This finding reflects a sample that was primarily treated by extraction.

6. The single most contributing factor to overbite correction in euryprosopic facial types was intrusion of the mandibular incisor which accounted for close to 46% of the overall change. This study supports other findings of the unlikelihood of molar extrusion in individuals of this facial type.

7. Although mesoprosopic individuals achieved over 50% of overbite correction from intrusion of the maxillary and mandibular incisors, BUI was almost cancelled out by the response seen in MXSK. If this effect is undesirable, headgear may be necessary in average facial types.

8. The parameters contributing most to overbite correction in leptoprosopic facial types is the mandibular incisor and anterior mandibular skeletal change. TLI, BLI, and MNSK contributed to about 72% of the overall change in overbite. The amount of mandibular incisor intrusion may be limited by growth.

Facial type is relevant where interactions occurred in this study and can aid in diagnosing and treatment planning excessive

overbite correction. Recommendations would include the continuation of vertical control in extreme facial patterns with more attention given to vertical control in mesoprosopic facial patterns due to the potential of an unfavorable response in the bony maxilla during treatment. More attempt can be made to increase maxillay incisor intrusion in leptoprosopic individuals since intrusion does not appear to be limited by growth in any facial type. Although significant tipping of the mandibular incisor may not be desirable in any facial type due to the instability associated with it (Simons and Joondeph, 1973) tipping may be a response observed due to the possible limitation of mandibular incisor intrusion in leptoprosopic individuals.

Differences as well as similarities exist between all facial types with respect to amount and direction of growth when considering a particular site or structure. Although growth was the factor controlled in this study, many other factors such as musculature are probably involved also.

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DEDICATION

To my father and beloved mother, who sacrificed many things so that I could pursue an education.

and

To my wife, Janice, whose love, support, and encouragement made this accomplishment possible.

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INTRODUCTION

Deep overbite correction has been a problem recognized for many decades. In 1928, Grieve described it as the most difficult problem in orthodontia. Through the years opinions have differed regarding the etiology of deep overbites and, consequently, how they should be treated. Moreover, it is thought that facial type and/or facial type indicators (SN-MP, FMA, OM angle, mandibular arc, facial axis, lower facial height) play a major role in predicting how an individual will respond to treatment (Schudy, 1968; Bench, et al., 1977; Engel, 1980). It is reasonable that a vertical discrepancy such as a deep bite can be studied from cephalometric measurements that evaluate vertical deviation from the norms but it is not clear whether changes in these measures accurately translate into treatment response.

The first issue that must be addressed is how a deep overbite can be corrected. At present, it is not completely understood. Although there are many treatment modalities designed to specifically "open the bite", the relative contributions of tooth movement, skeletal changes, and growth have not been fully studied in an attempt to account for treatment results.

In 1928, Grieve posed the question:

Where an appliance of any kind is placed to open the bite, does any one really know what takes place?

In 1986, Abdel-Kader states:

> Certain areas within the field of orthodontics remain unexplored or not fully studied. One such domain that requires further exploration concerns the nature and extent to which orthodontic correction affects tooth rearrangement in the jaws. For example, when...deep overbite is orthodontically corrected, tooth alterations are expected and do indeed occur. Two alternatives might be considered as responsible for such changes- orthodontic treatment might produce intrusion and/or extrusion of teeth. It is not known with certainty which of the two possibilities is correct.

There are basically four interrelated factors contributing to overbite correction. Molar extrusion, incisor intrusion, tipping of the incisors and differential growth of maxillary and mandibular structures interact to produce the final "orthodontic result" (Simons and Joondeph, 1973; Engel et al., 1980).

Overbite correction has been observed and studied by regional superimposition and various cephalometric analyses. Superimpositional methods have been limited to qualitative results. Individual amounts of tooth movements, however, have not been reported. Cephalometric measurements have been developed by many investigators to evaluate amounts of intrusion or depression of the dental units but genuine intrusion and labial tipping movements were often not separated as different components, thus leading to possible faulty conclusions. Investigators who have recognized that tipping changes influence incisor vertical height have not yet devised a method to account for how these variables interact (Castaldo, 1970; Barton, 1972; Carlyle, 1977; Otto, 1980; Engel et al., 1980).

Because of the importance of the vertical dimension in orthodontic treatment, an analysis was developed to study the interaction of tooth movement and skeletal growth for vertical changes during treatment. This analysis was applied specifically to evaluate the corrections of excessive overbite. Facial type was also studied to assess its value as a predictor of treatment response.

REVIEW OF THE LITERATURE

Etiology

Excessive overbite has been attributed to skeletal, dental, and neuromuscular features which act singularly or in combination with each other to produce this long recognized component of malocclusion.

Etiology- Dental factors

Bonwell (1925) from his work on artificial teeth stated that anterior overbite was determined by the depths of the cusps of the molars and premolars. These depths will vary from individual to individual.

Steadman (1949) stressed the relationship of the long axis inclinations of the maxillary and mandibular incisors to each other as an important etiological factor in overbite. He found overbite directly proportional to interincisal angle. Popovich (1955) also reported a strong relationship between interincisal angle and the overbite in his Class II deep overbite group. It was not as highly correlated with the Class I group. Schudy (1963, 1968) believed an actual cause and effect relationship existed between the interincisal angle and the amount of overbite. Other investigators (Ludwig (1967), Issacson (1970), Mills (1973)) have argued that a high interincisal angle and deep overbite were related but defined the relationship as an association.

Vertical eruption of maxillary and mandibular incisors was

implicated in the etiology of overbite by Jackson (1939). Mills (1973) studied Class II Division 2 deep bite cases and found a positive correlation (r = 0.246) between upper and lower incisor heights and excessive overbite indicating a slight over-eruption pattern. Wolfson (1938) as well as Smeets (1962) found only the lower incisor vertical height to be associated with overbite.

Fleming (1961) found low but significant correlations for the upper jaw only in females, and for the lower incisor only in the combined male and female group. Prakash and Margolis (1952) examined cephalometric radiographs of 120 individuals between 12 and 30 years of age. Breakdown according to sex was not given. A negative correlation (r = -0.450) between the lower molar height and overbite and a positive correlation (r = 0.400) between upper incisor height and overbite was found. This is consistent with several authors who believed a combination of infraeruption of posterior teeth and supraeruption of anterior teeth existed to produce a deep overbite (Strang (1934); Mershon, (1937); Steadman, (1940)).

Etiology- Skeletal

Diamond (1944) studied the vertical development of the ramus in relation to the dental height of the dentition. His sample consisted of Broadbent's composite cephalometric tracings, models of 12 children with delayed eruption, and one serial study from birth to 8 years of age. Diamond concluded that deficient growth

in the length of the ramus would inhibit the active eruption of the posterior teeth and allow the continuous eruption of the anterior teeth, resulting in a deep bite.

Two years later Wylie (1946) published a report refuting Diamond's theory. Wylie's sample included 90 cases, 61 female and 29 males. Angle's Classifications were not given. In contrast to Diamond, the sample consisted of individuals with no deciduous teeth. Wylie compared the ramus height of those cases 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 on the lingual gingival tissue) and found no significant difference in ramus height between the groups. However, Wylie observed that total face height, lower face height and molar height were significantly less in cases with severe overbite than in those with slight overbite. In addition to Wylie, Popovich (1955), studying Class I and Class II cases, found a significant correlation between lower facial height and overbite in the Class II cases. Mills (1973) found similar results from studying Class II Division 2 malocclusions.

Fleming (1961) studied casts and lateral cephalometric films of Class I individuals only from ages 9 to 16 years of age. He reported a significant but low negative correlation between ramus length and degree of overbite in males and females. His finding

supports the work of Diamond. This is in contrast to Popovich (1955) who did not find a significant relationship between ramus length and degree of overbite in his Class I group but found a relationship in his Class II group. Again there was a negative correlation between ramus height and overbite.

Schudy's (1963) observations were different than the previous investigators. He found that an increase in ramus height was associated with a deeper overbite. This was inferred from Class II Division 2 malocclusions exhibiting deep overbites and large rami. The correlation between overbite and ramus height, however, was $r = 0.12$, demonstrating a weak relationship.

Weinberg and Kronman (1966) examined 30 normal occlusions and 30 malocclusions where the overbite was greater than 5 mm. No other criterion for classification was used. Although the lower facial height was less in the malocclusion group than in the control group, the results were not significantly different.

Richardson (1969) through the use of a facial polygon defined by the cephalometric points nasion, sella, articulare, gonion, and menton attempted to find differences in craniofacial morphology in anterior open bite and deep overbite cases which may influence face height and the incisor overbite. Cephalometric radiographs of 110 open bite cases and 110 deep bite cases were studied. The ages ranged from 7 to 27 years. There was an average decrease in lower face height in the deep bite cases compared with the open

bite cases. The upper facial height in both groups were similar. He found no direct relationship between the size of the mandible and joint angles and the lower face height in both groups. Two variables, ramus height and mandibular body length, together, had an inverse relationship with jaw angle. Thus increases in ramus height and body length which would be expected to increase lower facial height are nullified by a reduction in the jaw angle. Accordingly, Richardson concluded that in deep overbite, shape is much more important than size. Based on the cephalometric plane sella-nasion he found that the anterior part of the cranial base is significantly larger in deep overbite. To test this finding Moss and Salentijn (1971) compared tracings of "actual" anatomic anterior cranial base outlines and found no differences. In reference to the relatively acute gonial angle in deep bite cases their findings agreed with Richardson's i.e. the difference in mandibular form is due to factors of shape not size.

Trouten (1980) examined untreated deep bite, open bite and normal cases utilizing Enlow's counterpart analysis. There are two advantages of studying the skeletal relationships in these malocclusions by this analysis. First, the planes utilized correspond to actual fields and sites of growth and remodeling in contrast to standard cephalometric planes and angles. Thus, actual anatomic evaluation can be made. Second, the individual becomes his own anatomic norm, rather than compared to population

standards or norms. Fifteen subjects in each of the three groups were studied for a total of 45. Although each group was then separated into Class I and Class II cases the differences found were not significant and, consequently, the groups were combined. In comparing deep bite group to the open bite sample Trouten found the following to be characteristic of deep bite: a closed gonial angle, upward aligned mandibular plane, flatter occlusal plane, deeper Curve of Spee, lesser palatal depth (from ANS to the midline of the palate), greater ANB angle, greater maxillary protrusive tendency, lesser posteriorly aligned ramus, decreased vertical PM dimension (occurs when the ramus rotates less than the middle cranial fossa), upward corpus-occlusal rotation in relation to the ramus rotation, and a clockwise rotation of the palatal plane during vertical development of the nasomaxillary complex. Shields' findings (1985) that deep overbite subjects have a tendency toward lower SN-occlusal plane, SN-Y axis, and SN-mandibular plane angles and higher SNA and SN-Pg angles support Trouten's findings. Although no correlations with facial type were done, this facial pattern would appear to be more brachycephalic than average.

Etiology- Combination

Grieve (1928) called the excessive overbite a "sympton" caused by either the protrusion of maxillary teeth, a deficient mandible, or a combination of both. He felt any distal relationship of the mandibular to the maxillary teeth could be responsible. Thus, Grieve attributed deep bites to an anteroposterior problem.

Baume's (1950) findings support those of Grieve. In a longitudinal study of 52 patients before and after the eruption of the permanent incisors, he observed that the less the mandible grew forward during the eruption of these teeth, the deeper the bite. He concluded that horizontal mandibular growth was important in the determination of overbite.

Strang (1934) and Hemley (1938) both believed vertical overlap was due to either the "supraclusion" of the incisors, or "infraclusion" of the molars, or a combination of both. Strang felt that he could locate which part of the denture was at fault by analyzing facial photographs or by clinically examining the patient. The incisors were responsible if the patient exhibited balanced facial harmony with a deep overbite. The molars were at fault if the patient had a short lower third of the face, however, both Strang and Hemley implicated muscular forces as an important factor in the development of excessive overbite.

Mershon (1937) divided excessive overbites into "true closed

bites" and "deep overbites". The difference between the two was defined in the location of the discrepancy. "True closed bites" have posterior teeth that are undererupted while "deep bites" have anterior teeth that are overerupted. True closed bites, according to Mershon, cannot be corrected because "heavy facial muscles are involved which dominate over bone". He postulated that "deep overbites" do not involve muscles and are, therefore, amenable to treatment by intruding the anterior teeth.

Haberle (1941) felt that the vertical dimension in excessive overbite was either increased in the incisor region, decreased in the molar region, or that both could be present. He felt that the excessive overbite was attributed to labial flaring of the maxillary anterior teeth, collapse of the mandibular denture, or a distal relationship of the mandibular denture.

Popovich (1955) studied the dental models and lateral cephalograms of 102 patients, ages 18 to 25. He found that the factors contributing to excessive overbite varied with the type of occlusion. Class I malocclusions were controlled by dental factors such as length of the incisors and molars. In Class II cases, however, skeletal factors combined with dental factors to produce the excessive overbite. The skeletal factors responsible were lower facial height and a shortened ramus height.

Sassouni and Nanda (1964) characterized deep overbite by "well established" associations presented by other investigators.

These skeletal as well as dental characteristics represented a summary of the conclusions of previous investigators. Deep overbite was associated with 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. These characteristics included both vertical as well as anteroposterior discrepancies. Sassouni and Nanda concluded that the anteroposterior imbalances were less significant than imbalances in the vertical dimension.

Sassouni and Nanda selected 8 adults with skeletal deep bites and 8 adults with skeletal open bites based on their description that had longitudinal cephalometric records available from birth. Average tracings were derived from each group and then superimposed on: anterior cranial base; the palate at PNS; the mandible at the symphysis and lower border; and, the condyles at articulare. They not only confirmed their original description of the skeletal malocclusion but they also found that although the gonial angle is smaller in the skeletal deep bite and there was no difference in the total length of the mandible between both groups. Their finding that the posterior vertical growth (PNS-Go) exceeds the lower anterior facial growth (ANS-Me) also supported the smaller gonial angle in the skeletal deep bite sample.

Sassouni and Nanda proposed a theory regarding muscle forces

from their observations that the extrusion of the incisors in open bite and extrusion of the molars in deep bite results in relapse. They proposed that the internal pterygoid, masseter and temporalis muscles constituted a "posterior vertical chain of muscles" which produced a different vector of force in deep bite versus open bite cases. In open bite cases these muscles exert an oblique force posterior to the molars while in deep bite cases, the muscle forces are more perpendicular and more anteriorly situated and, therefore, exert most of their force against the molars. This would tend to keep them depressed.

Findings from Proctor and DeVincenzo (1970) do not support those of Sassouni and Nanda. They found no apparent differences in the attachment sites of the masseter muscle in skeletal open bites and deep bites. Also, there were no differences in the angular relationship between the mean direction of the muscle fibers and the occlusal planes between the two groups. Differences were found, however, in the position of the masseter muscle fibers relative to SN, Frankfort, palatal and mandibular planes. Moss and Salentijn (1971) on the basis of Proctor and DeVincenzo's findings state that the masseter muscle is positioned normally but the capsule within which this muscle exists is abnormal in skeletal deep bites since the SN, Frankfort, palatal and mandibular planes were considered malpositioned. They disagree, therefore, with Sassouni and Nanda that skeletal deep

bites reflect a "differing level of function" of the muscles of mastication.

Barton (1972) concludes from his own literature review that the etiologic factor most likely involved in excessive overbites (dental) is the eruption of teeth to positions that are ultimately determined by an individual's muscular pattern.

Carlyle (1977) studied overbite relationships in 87 orthodontic patients using digitized coordinates from lateral cephalometric radiographs. Pooled correlations of Angle malocclusion and sex subgroups were assessed to examine the relationship of overbite to various dentofacial measurements. He found that deep overbite regardless of Angle classification or sex is associated with diminished dentoalveolar vertical molar heights, retrusive mandibular incisors, and a smaller and/or dorsally positioned mandible relative to the maxilla and/or anterior cranial base. He hypothesized that this variability in mandibular morphology attributed to his associations of anterior total face height, lower face height, mandibular incisor position, occlusal plane and mandibular plane with excessive overbite. He did not find any association between increased incisor dentoalveolar vertical height and deep overbite.

Facial Type and Overbite

The purpose of this section is to examine the relationships found in the literature between facial pattern and excessive

overbite. In addition, the influence of facial type on the orthodontic correction of overbite will be explored.

Wylie (1946) evaluated ninety cases and found a significant relationship between the vertical overbite and the total facial height. He concluded that the total facial height diminishes with an increase in the depth of overbite. Bjork (1947) reported a similar finding using the angle between the mandibular plane and the occlusal plane. He noted, that the group with the greater overbite also had the smaller occlusal-mandibular angle.

Sassouni and Nanda (1964) concluded that the internal pterygoid, masseter and temporalis muscles constituted a vertical chain of muscles that exerted forces perpendicular to the molars in occlusions where deep overbites existed. They hypothesized that extruding molars in these patients would not be advised because muscular forces would keep them depressed. They suggested that the posterior teeth be brought more anterior to lessen the force of the vertical chain of muscles.

Schudy (1966) also identified the occlusal-mandibular (OM) plane as having a significant correlation with vertical overbite. Although Schudy identified similar basic skeletal characteristics as Sassouni and Nanda, Schudy's observation was that molars were very rarely depressed into bone by muscle pressure. He also felt that the intrusion of mandibular incisors for overbite correction will subsequently extrude. Schudy (1963) examined 400

malocclusions and divided them on the basis of the OM angle. Group I included what he considered normal OM angles from 11 to 20 degrees. Group II included those cases where the OM angle was greater than 20 degrees while the OM angle in Group III was below 11 degrees. He concluded that the amount of overbite was significantly dependent on facial pattern because the average overbite was found to be twice as great in Group III than in Group II.

Ludwig (1967) felt that Schudy's sample in Group II had too many "open bite" cases and that the range of overbite in his sample (4 mm open bite to 10 mm overbite) was too great. He set up a sample that was similar to Schudy's, except that Ludwig looked at a smaller sample of 41 cases where both Groups II and III had deep overbites of at least 5 mm. Group II had OM angles over 18 degrees and Group III had OM angles less than 11 degrees. Pretreatment overbites in Group II had a mean of 6.2 mm while the mean overbite in Group III was 6.8 mm. Based on his sample, Ludwig concluded that there was no significant correlation between pretreatment overbite and the facial pattern of the individual.

Ludwig also studied 100 cases whose facial patterns were differentiated not by the OM angle but by the dental height to facial depth ratio. Dental height was established by the distance between gnathion and the anterior nasal spine parallel to the facial plane. Facial depth was established along a plane

perpendicular to the facial plane to basion. Inclusion in the study required that the pre-treatment overbite be 5 mm or more and that a satisfactory treatment result was attained. He found no correlation of facial pattern to the overbite at pre-treatment, post-treatment, retention, or post-retention (2 to 8 years).

Creekmore (1967) evaluated vertical growth increments in untreated controls and treated cases to document the influence of orthodontic treatment on the vertical growth of the face. Examination, however, consisted of "average" facial types (SN-MP range of 25.5° to 38.5°). He found that vertical growth of the teeth is not uniform. Posterior and anterior teeth have different eruption patterns. Specifically, maxillary molars moved inferiorly more than maxillary incisors and mandibular incisors erupted superiorly more than mandibular molars. In "average" facial types with supposedly "normal" growth, this caused the occlusal plane to move inferiorly in the posterior area. Creekmore and Schudy both agreed that orthodontic treatment significantly extruded mandibular molars a greater amount than that observed in the untreated group. This had an effective bite opening response. They also concluded that orthodontic treatment also inhibited the eruption of the mandibular incisors.

Price, corroborating with Creekmore (1967) studied 25 high mandibular plane angle and 25 low mandibular plane angle patients (SN-MP angles not stated). These two groups were compared with

each other and were then compared to Creekmore's untreated sample. They showed that high angle cases without orthodontic treatment are more susceptible to vertical development than average facial types whereas low angle cases are less susceptible than the average. High angles were found to become increased with growth while low angle facial types tended to decrease SN-MP angle. Creekmore concluded that low angle cases with ecxessive overbites are difficult to correct because they are resistant to the vertical eruption of posterior teeth. He concluded that one must in these cases depress anterior teeth that are already infraerupted. Creekmore added that different facial types should be orthodontically treated with very different mechanics.

Schudy (1968) expanded on Creekmore's study by adding that the degree of overbite does not indicate how an individual will respond to treatment as much as the individual's facial type. Large SN-MP, FM, and OM angles are characteristics that Schudy found to have a greater likelihood for long term overbite correction. Schudy found that the OM angle had the highest correlation in judging bite opening potential.

Kuhn (1968), in regards to facial type and musculature, states that "orthodontists have perhaps subconsciously attempted to read muscle force into a head film". Although a correlation exists between low mandibular plane patterns and weak muscle forces, Kuhn did not feel that the relationships were absolute.

In his experience with excessive overbite correction, high angle cases may resist vertical eruption of the molars while low angle cases may open easily.

Burstone (1977) believes that patients with excessive overbite, flat mandibular planes, and well-developed musculature probably do not experience extrusion of the molars to open the bite because the muscles of mastication intrude them to their original positions.

Engel (1980) cites a thesis by Cornforth who studied mandibular rotation during and after treatment. His results indicated that a strong mandibular arc (the small angle between the corpus and condylar axes) associated with a deep bite in a brachycephalic individual would be an indication that clockwise rotation of the mandible during treatment would be difficult. He concluded that correction of the excessive overbite would necessitate incisor intrusion.

Otto, Anholm and Engel (1980) examined the effect of facial type on the amount of incisor intrusion during treatment. Previous investigators (Ricketts, 1964; Bench et al., 1978) have implied that morphology of the symphysis correlated with the ease or difficulty of intruding mandibular incisors. Specifically, they felt that brachycephalic individuals have wider symphyses that may allow for easier depression with the opposite for dolicocephalic cases. Fifty-five cases were studied

cephalometrically and were classified as being dolicofacial, mesofacial, or brachyfacial on the basis of a "facial type vertical number". This number was determined by measuring the facial axis, lower face height, mandibular plane, mandibular arc and facial angle. The number of standard deviations from the mean was then determined for each of the above measurements. Dolicofacial type measurements were assigned negative values while brachyfacial deviations were assigned positive values. The total standard deviations from the mean were added together and averaged (divided by 5) to arrive at the facial type vertical number. Although Otto states that there is no significant influence upon the amount of intrusion achieved on the basis of facial type the materials and methods used are questionable. It is unclear what standard deviation Otto assigned dolicofacial type measurements versus brachyfacial type numbers. Sample size and distribution need to be considered since the mesofacial sample composed 35 of the 55 total cases. He had 1 child and 5 adults in the dolicofacial group and 7 children and 7 adults in the brachyfacial sample. He states a statistically adequate sample size was attained, except in the case of the dolicofacial group. Most investigators agree upon the treatment objectives in extreme facial patterns. For very short faces, eruption of posterior is advocated whereas in long faces extrusion of posteriors should be avoided (Ricketts, 1960; Burstone, 1977).

Disagreements arise in the stability of these tooth movements. Differing points of view are seen even when "average" facial patterns are presented. Basically, two schools of thought exist. One philosophy advocates mechanics to intrude incisors whether it consists of primarily maxillary incisor intrusion (Burstone, 1977), maxillary incisors only with no mandibular incisor intrusion (DiGiulio, 1983), or primarily mandibular incisor intrusion (Engel, 1980). The other philosophy advocates the extrusion of posterior teeth (Schudy, 1963; Creekmore, 1967).

Growth and its Effect on Overbite

Using a longitudinal study of 322 Swedish boys from 12 to 20 years of age, Bjork (1953) found a general decrease in overbite with age. However, the range of variation was quite large. He also found that deep overbites had a greater tendency to open than normal overbites. Again, individual variation was high.

Schudy (1968) from a random collection of 62 individuals 11 to 14 years of age found that the growth increments of six anatomic areas were relevant to overbite. These areas were the condyles, maxilla, posterior alveolar process of maxilla and mandible, and vertical growth of the anterior process of the maxilla and mandible. Because 70% of the total vertical growth of the face was attributed to the downward growth of the maxillary molar teeth, Schudy claimed this was the most important factor in establishing facial height as well as affecting overbite.

However, there was considerable variability in his results reflecting the random nature of the sample.

Bjork and Skeiller (1972) have shown with metallic implant studies that growth rotations of the mandible may increase or decrease overbite.

Many longitudinal studies (Baume, 1950; Bjork, 1953; Moorees, 1959; Herness, et al., 1973; Moyers, 1976) have attempted to study the changes in the amount of overbite of the incisors with age. There is lack of agreement among investigators since overbites have been reported to increase and decrease with age as well as plateau at a certain age. Consistent in all these studies were the wide range of values found indicating marked individual variability.

Treatment Effects versus Growth Changes

There is obvious difficulty in separating orthodontic treatment effects from changes that would have occurred from growth alone. This problem was recognized as early as 1938 by Wolfson. Some studies have addressed this problem through the use of untreated controls (Creekmore, 1967; Forsberg and Hellsing, 1984; Lawrence, 1985). Others have devised cephalometric measurements that represent growth areas that can then be factored out, leaving apparently the dental change due to treatment (Thompson, 1979; Otto, 1980). Atkinson (1980) implemented a coefficient which was then applied to Johnston's prediction grid.

Johnston (1986) used sex-specific growth curves to yield a coefficient which he called expected growth units. Since it is obviously necessary to have some method to differentiate growth changes and treatment effects these techniques will be explained in more detail at this time. This is extremely important in the study of overbite correction since studies have shown that deep overbites tend to improve through the passage of time even without treatment (Bjork, 1953; Fleming, 1961). In contrast, some previous studies have not addressed the role of growth at all in overbite correction (Castaldo, 1966; Barton, 1972; Carlyle, 1977).

Thompson (1979) evaluated changes in mandibular molar position and in the positions of the maxillary and mandibular incisors relative to the occlusal plane and the overbite corrections accomplished with the Begg technique. He evaluated mandibular incisor height changes from two positions. One from the incisal edge to mandibular plane and the other from the incisal edge to Steiner's point "D". Two reference areas were used to account for growth alterations at point menton. Two reference lines were also used for the maxillary incisor. Maxillary incisor height was measured along a perpendicular line from sella-nasion to the incisal tip. Growth of the midface was measured on a perpendicular line from sella-nasion to A point. He concluded that treatment mechanics extruded the mandibular molar 3.5 mm, intruded the mandibular incisor 1.4 mm, and intruded

the maxillary incisor 1.4 mm. The net result of these dental changes was a flattening of the mandibular occlusal plane angle.

Otto, Anholm, and Engel (1980) accounted for growth effects of the maxillary and mandibular incisor by measuring vertical changes at anterior nasal spine (ANS) and suprapogonion (PM) at pretreatment and posttreatment. They used Frankfort horizontal as the horizontal reference plane. They subtracted the change at ANS from the change at PM and calculated a mean value of 2.5 mm. This represented the extrusive effects of growth on the teeth. Only total incisor intrusion could be measured because the growth factor could not separate individual amounts of maxillary and mandibular growth.

Atkinson (1980) studied the impact of facial morphology on the relative contribution of growth and treatment to the orthodontic correction of Class II Division 1 malocclusions. In assessing variations in the final result due to growth, he used a prediction technique that was individualized instead of averaged. A "coefficient of expected growth" was employed to estimate an individual's growth potential. The coefficient was based on a patient's age, sex, and duration of treatment which was then applied to Johnston's "grid" predictions.

Johnston (1986), in comparing the treatment effects of different Class II modalities (edgewise, Begg, and functional appliances) found it necessary to determine the effects of

treatment on growth. Given that the amount of growth is a function of age, sex, and treatment time, he employed Rocky Mountain Data System's sex-specific growth curves and took the area under the curve which corresponded to the patient's treatment period and divided it by the area under the curve representing the patient's minimal prepubertal year. "Expected growth units" thus represented an untreated individual's growth potential based on age, sex, and length of treatment.

Defining Intrusion/Depression

Intrusion or depression as used in the literature appears to have several different meanings. For those who have defined it, results can be interpreted with respect to a specified tooth movement, however, definitions have not always been supplied.

McDowell (1970) differentiated between true intrusion and what Thurow (1962) called a "tipping depression". If the mandibular incisors are tipped forward, the incisal edges will also tip down which would give the clinical appearance of intrusion.

Burstone (1977) explained this movement as "pseudo-intrusion", defined as the "labial tipping of an incisor around its centroid", having similar meaning as Thurow's "tipping depression". Burstone referred to genuine intrusion as the "apical movement of the geometric center of the root (centroid) in respect to the occlusal plane or a plane based on the long axis of

the tooth". Otto (1980) utilized these definitions to describe tooth movements seen in the bioprogressive technique.

Sassouni and Nanda (1964) defined depression as "holding the tooth while the alveolar process is growing occlusally". They concluded that although teeth can be depressed the limit of depression is the growth potential of the alveolar process. The probability, therefore, that depression will occur in a young patient with favorable mandibular growth is good while depression in an adult would be highly unlikely. Creekmore (1967) used the term depression to describe a more gingival positioning of the centroid of the teeth when superimposed on their denture base. Kesling, stated in his thesis (1968) that a sign of actual depression is when a tooth does not "elongate while being tipped to a more upright position" (from Thorton, 1981).

Liu and Herschleb (1981) admit clarity does not exist in regards to terminology such as intrusion. Although the conventional definition of genuine intrusion is the translation of incisors along their long axis, this movement requires a vertical as well as a horizontal force because the center of resistance is moved upward and backward for maxillary incisors. They suggest a new method of defining tooth movement by its horizontal and vertical components within a coordinate system. Also, the axial inclination should also be measured and expressed by the angle formed by the long axes of the tooth at pre-treatment and post-

treatment positions. Thus, pure intrusion defined by Liu and Herschleb would consist of a pure vertical displacement of the center of resistance where the axial inclination of the tooth remains parallel. Bulcke, et al. (1986) studying the center of reistance of anterior teeth during intrusion and Dermant and DeMunck (1986) studying apical root resorption caused by intrusion adopted Liu and Herschleb's concept of pure intrusion.

Measuring Intrusion/Extrusion

Wolfson (1938) was one of the earliest to attempt to measure changes utilizing a bite plate to correct deep overbites. He used dentofacial casts in which the stone models of the teeth to a fixed portion of the face could be registered. He found changes mainly occurring in the anterior region, and more markedly in the mandibular incisor region. Prior to this time, Mershon (1937) believed the result of using a bite plate was depression of the mandibular incisors by clinical impression.

Hemley (1938) employed external measurements to observe how deep bites were corrected with the bite plate. He measured with callipers the height from the incisal edge of the incisors to the lower border of the mandible. He also measured from the mandibular first molar to the inferior border of the mandible before and after treatment. He found that bite plates had no effect on lower incisors but opened the bite by eruption of the posterior teeth.

Bahador (1944) was one of the first to use a cephalometric analysis to study the treatment effects of bite plates. He measured the posterior dental height of the mandibular molar by a perpendicular line from a point on the molar to a line tangential to the lower border of the mandible. For mandibular incisor height, changes were measured from the incisal edge perpendicular to the same line measuring the lower molar. Posterior dental height of the maxillary molar was measured by a perpendicular from a point on the maxillary molar to the sella-nasion plane. Maxillary incisor height was not measured. This study did not evaluate angular changes. No controls for growth were used although the treatment period varied between 2 to 8 months. Bahador found an increase in the posterior dental area in all cases and little change in the height of the mandibular incisors.

Creekmore (1967) used perpendicular lines from Frankfort horizontal to assess "vertical growth increments" of incisors and molars. He used ANS-$\underline{1}$ and $\overline{1}$-Mn to measure the vertical behavior of the maxillary incisor and mandibular incisor respectively. The maxillary molar was measured from a point on the maxilla to a point on the molar while the mandibular molar was studied from a point on the mandibular molar to the mandibular plane. The specific points were not defined nor were angular changes of these teeth measured. Additionally, although an untreated population was used as controls the sample was not matched for age, sex, or

class of malocclusion.

Castaldo (1970) studied tooth movements contributing to overbite correction of a least 3 mm or more in patients treated with an anterior high-pull headgear. He used angular and linear measurements taken from standard cephalometric planes with particular emphasis on the movements of the incisor and molar teeth and the tipping of the palatal plane. To evaluate changes in tooth position due to general facial growth and orthodontic treatment, the anterior cranial fossa was used for superimposition of pre- and post-treatment films and a coordinate system was used to measure the differences. Regional superimposition of the maxilla and mandible was used to evaluate changes due primarily to orthodontic treatment. Intrusion and extrusion was measured from a perpendicular line extended from the palatal plane to the incisal edge of the maxillary incisor and to the mesiobuccal cusp of the maxillary molar. Extrusion and intrusion of the mandibular incisor was measured by a perpendicular line extended from the mandibular plane to the incisal edge while the mandibular molar was measured from a perpendicular line from the mandibular plane to the mesio-buccal cusp. Castaldo found that the mandibular molar was the primary factor in correcting the overbite while anterior high pull headgear had little success in intruding the maxillary incisors or tipping the palatal plane. Similar means were used by Barton (1972), Carlyle (1977), Forsberg and Hellsing

(1984), and Lawrence (1985) to measure vertical changes in overbite correction. Angular changes were also measured in these studies.

Thompson (1979) examined mandibular molar, mandibular incisor and maxillary incisor changes in relation to overbite changes. While mandibular molar and incisor heights were measured similarly to Bahador (1944) and Castaldo (1970), maxillary incisor height was measured on a perpendicular from the sella-nasion plane to the incisal tip. No evaluation of tipping was done.

Sondhi (1980) examined interactions between certain dimensional changes occurring during orthodontic treatment and the post-retention stability of these changes. Individual tooth movements in a vertical or horizontal direction were measured by regional superimposition of the maxilla and mandible on a best fit basis. Changes were measured from the transfer axis which was the pretreatment palatal plane. Tipping of the incisors were measured in this study.

Otto, et al. (1980) studied the amount of incisor intrusion attained with the bioprogressive philosophy in adults versus children categorized by facial type. Dome templates were used to trace incisors that were oriented on the long axis and registered on the incisal edges. Intrusion and long axis changes were measured at the root apices after maxillary and mandibular superimpositions. Incisal templates were used to give a

consistent orientation of the apices of the teeth from pre-treatment and post-treatment cephalograms since variable root resorption was expected. Measuring intrusion at the root apices was selected since the investigators felt a more accurate assessment of bodily intrusion was obtainable.

Liu and Herschleb (1981), in examining intrusion and retraction of maxillary incisors with the Begg technique used an analysis that involved the center of resistance of the maxillary central incisors in pre-treatment and post-treatment positions. The center of resistance was arbitrarily defined as 40 percent of the root length. Root length was defined as the distance from the alveolar bone crest to the root apex. The anticipated post-treatment position of the incisor was drawn on the pre-treatment cephalogram since this was an analysis done before treatment to design the proper force system to intrude and retract the upper incisors. A coordinate system was drawn with its origin at the center or resistance of the pretreatment maxillary incisor and the abscissa parallel to the palatal plane. The projected distances from the center of resistance of the desired posttreatment maxillary incisor to the X and Y axes indicated the amount of respective intrusion and retraction required.

Cephalometric measurements attempting to analyze vertical tooth movement to correct deep bites have measured changes from the incisal tips, root apices, and the centroid. It would seem

from the literature that intrusion should be measured from the centroid (Burstone, 1977) due to the limitations with the other methods. Measurements from the incisal tip can be in error since this is the point most affected by tipping changes. Measuring intrusion from the root apices has the obvious problems resulting from changes in root length due to external root resorption.

While a few studies have attempted to evaluate intrusion by dental movement alone, most have erroneously interpreted vertical changes in tooth position as intrusive or extrusive movements without calculating the vertical changes due to dental tipping.

STATEMENT OF THESIS

Molar extrusion, incisor intrusion, tipping of the incisors and differential growth of maxillary and mandibular structures are four interrelated factors that can contribute to overbite correction. At present, the exact nature of tooth movements that combine to correct a deep bite have not been determined because of a lack of an adequate method that can quantitate the relative contributions of orthodontic dental changes, skeletal changes and growth. It is thought that the facial type of an individual influences the contribution of growth and treatment effects to the orthodontic correction of a deep overbite.

It is the purpose of this study, therefore, to develop such a method and to utilize it to examine the significance of facial type on the relative contributions of treatment and growth to the orthodontic correction of a deep overbite.

MATERIALS AND METHODS

Sample

This study examined the cephalometric records of 100 patients treated by residents at the Case Western Reserve University Orthodontic Department. Criteria for selection consisted of the availability of adequate pre-treatment (T1) and deband cephalograms (T2) and the pre-treatment condition of a deep overbite. Sample selection was not based on the orthodontic result since the outcome could then be biased.

Normal or ideal overbite has been reported in percentages, millimeters, and in certain incisal relationships. Neff (1949) wrote that ideal overbite was 20% while Moorrees (1959) found his sample to have an overbite range of 35% to 40%. Steadman (1952) found overbite to range from 0.5 mm to 4.3 mm with a mean of 3.1 mm. Williamson (1976) and Fox (1984) have shown that proper incisal guidance and thus ideal overbite can be attained when the lower incisor rests on the cingulum of the maxillary incisor. On the basis of the requirements of a functional occlusion an overbite was defined to be excessive when the lower incisal edge was beyond the cingulum of the maxillary incisor. This was determined cephalometrically, but if any questions remained, the pre-treatment models were examined also.

The sample was separated into euryprosopic (wide and short), leptoprosopic (narrow and long), and mesoprosopic (intermediate)

facial types by the use of anthropometric values. This necessitated the availability of both lateral and frontal cephalograms since the facial index is calculated by the skeletal length from Nasion to Menton (× 100) divided by the bizygomatic breadth. This was measured with a millimetric ruler accurate to the nearest 0.5 mm. The breakdown according to Montague (1960) is as follows:

Hypereuryprosopic	XX.X - 79.9
Euryprosopic	80.0 - 84.9
Mesoprosopic	85.0 - 89.9
Leptoprosopic	90.0 - 94.9
Hyperleptoprosopic	95.0 - XX.X

Twelve of the 100 patients did not have a frontal cephalogram in their files. In these cases, clinical frontal and profile photographs (2 1/2" × 3 1/2") were used to measure the soft tissue facial index. The validity of this method was examined by measuring the facial index both radiographically and photographically on 25 patients. A 1.6 mean difference was observed which was consistently lower than the radiographic value except in 2 cases. This error, if in the same direction, would have only affected 1 case. A paired t-test, however, showed this difference to be significant at the 95% level.

The control group consisted of 92 untreated deep overbite subjects from the Bolton Study (CWRU; Cleveland, Ohio) who were classified by a facial type in the same manner as the treatment group. All cases in the control had frontal and lateral headfilms

available. The original intention of this study was to use untreated matched controls. This would have been possible for the mesoprosopic and leptoprosopic group, but, less than half of the euryprosopic group could be matched due to an insufficient control population. Thus, the tracings in all the control groups were based on the mean age of their corresponding facial type in the treatment group.

Patients were stratified on the basis of facial type, orthodontic technique employed, auxillaries employed (headgear, elastics, biteplate, etc.), sex, extraction or nonextraction, and age (see Appendix I, II). Separation based on Angle classification was not examined since Trouten (1980) found no significant differences using Enlow's Counterpart Analysis between Class I and Class II cases.

Patients that were beyond 14, if female, and 18 years of age, if male, when started for othodontic treatment were removed from the experimental group since they were beyond significant growing years (Broadbent et al., 1975). This reduced the treated group from 100 to 96 (See Table I for a description of the sample).

Technical Details

Tracings were made on .003" matte acetate with a 0.5 mm H lead mechanical pencil. Sufficient landmarks were traced to allow identification of 16 registration points (see Table II, and Fig. 1).

TABLE I

DESCRIPTION OF SAMPLE

Treated group				Mean Ages Male		Female	
Facial Type	N	Male	Female	T1	T2	T1	T2
Mesoprosopic	36	23	13	13-2	16-0	12-10	15-11
Leptoprosopic	32	15	17	13-3	15-11	12-10	15-9
Euryprosopic	26	10	16	13-2	15-9	12-6	15-8

Control group				Mean Ages Male		Female	
Facial Type	N	Male	Female	C1	C2	C1	C2
Mesoprosopic	43	25	18	13-0	15-10	12-10	15-9
Leptoprosopic	38	21	17	13-1	15-11	12-10	15-5
Euryprosopic	11	4	7	13-1	15-9	12-4	15-11

Figure 1. Points used for the digitization of cephalometric tracings.

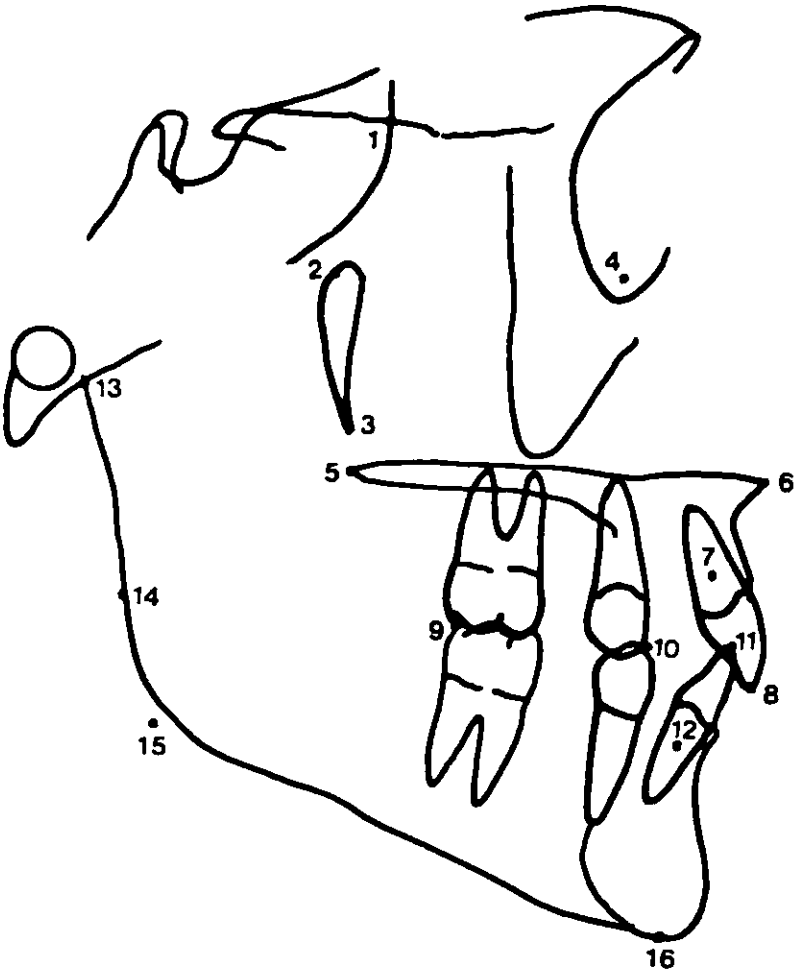

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TABLE II

LANDMARKS USED FOR DIGITIZATION

1. Sphenoethmoidal Junction (SE)
2. Foramen Rotundum in the Pterygomaxillary Fissure
3. Inferior-most Point of the Pterygomaxillary Fissure
4. Three (3) mm Above Orbitale
5. Posterior Nasal Spine (PNS)
6. Anterior Nasal Spine (ANS)
7. Center of Resistance (CR) of the Upper Incisor
8. Incisal Edge of the Upper Incisor
9. Most Posterior Occlusal Point of the Last Fully Erupted Maxillary and Mandibular Molars
10. Most Anterior Maxillary/Mandibular 1st 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)

Standardization Point-Middle of Ear Rod

The two radiographs for each individual were labeled as follows:

T1 = Pre-treatment film	C1 = First control film
T2 = Deband film	C2 = Second control film

All the landmarks were traced directly from T1 (or C1) to T2 (or C2) radiographs with the exception of the center of resistance (CR) for the upper and lower incisor which was transferred by use of a template. The CR for the incisors has been arbitrarily set as 40% of the distance from the alveolar crest to the root apex (Liu and Herschleb, 1981). This distance was measured with a caliper (Beerendonk, Seitz and Haag) which is accurate to the nearest 0.1 mm and was marked on the long axis of each incisor at T1. The CR point was transferred to the T2 tracing by registration on the incisal edges. All registration points were punched with the point of an Alvin divider to aid in locating the points with the stylus when digitizing. Intra-investigator tracing error was assessed by retracing 20 patients who were chosen at random. Digitization error was assessed by redigitizing the tracings of 10 patients.

Sixteen points and a final standardization point were digitized in sequence on a Summagraphics pad which orients points based on a x-y coordinate system. The computer facilities used in this study are housed in the Bolton Study and A. R. Jennings

Computer Center (CWRU). Six linear measurements and one angular measurement were then calculated by a program placed by the investigator. Five T1 and T2 radiographs were analyzed by hand to verify the data generated by the computer.

The 6 linear measurements yield 7 variables which form the basis of the analysis (see Figs. 2 and 3). All linear measurements were measured from a perpendicular to the horizontal reference line (Pterygoid point to a point 3 mm above Orbitale). This line has been reported by Enlow (1982) and Moss (1967) to be a stable plane that represents the path of the maxillary nerve and approximately parallels the palate during development.

The following abbreviations will be used to explain the method of obtaining the anterior vertical analysis (see Fig. 2 and 3).

Measurement 1 (M1) = Distance from the reference line to ANS.

Measurement 2 (M2) = Distance from the reference line to CR of the maxillary incisor.

Measurement 3 (M3) = Distance from the reference line to the incisal edge of the maxillary incisor.

Measurement 4 (M4) = Distance from the reference line to the incisal edge of the mandibular incisor.

Measurement 5 (M5) = Distance from the reference line to the CR of the mandibular incisor.

Measurement 6 (M6) = Distance from the reference line to Me'

Maxillary skeletal change (MXSK) is represented by the

Figure 2. Six linear measurements (M1, M2, etc.) and one angular meaurement (M7) generated by the computer.

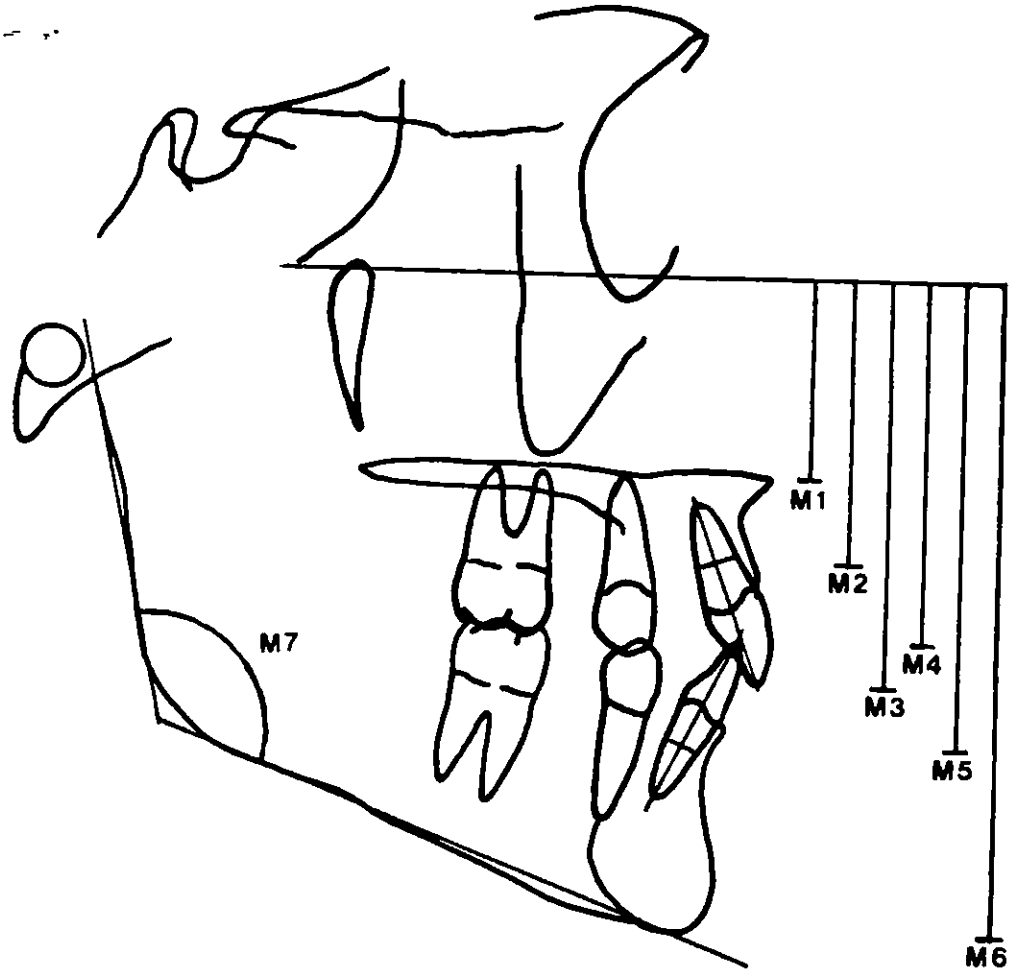

M1
M2
M3
M4
M5
M6
M7

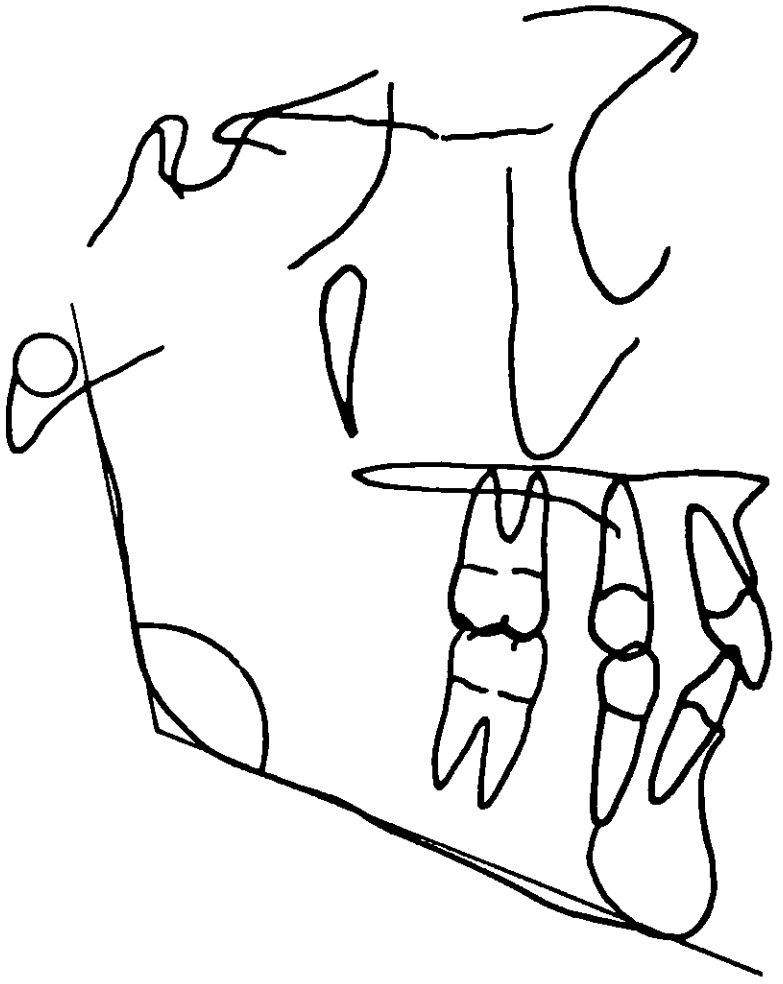
Figure 3. Anterior vertical analysis used in this study. The six linear measurements yield seven variables. Variable #1: MXSK = M1. Variable #2: BUI = M2 - M1. Variable #3: TUI = M3 - M2. Variable #4: TLI = M5 - M4. Variable #5: BLI = M6 - M5. Variable #6: MNSK = M6 - M1. Variable #7: OB = M4 - M3.

change in length from the reference line to ANS which is measurement 1 (M1). Bodily movement of the upper incisor (BUI) evaluates the amount of extrusion or intrusion and is calculated by subtracting M1 from M2. Vertical changes of the upper incisor due to tipping (TUI) is assessed by M3 - M2. Tipping (TLI) and bodily movement (BUI) of the lower incisor is represented by M5 - M4 and M6 - M5, respectively. Mandibular skeletal change (MNSK) is calculated by M6 - M1 while overbite (OB) is measured by M4 - M3. MNSK is a measure of mandibular skeletal displacement. By definition, molar extrusion accompanies increased MNSK change.

Since the shape of the mandible has been considered as more important than size in the deep overbite patient (Richardson, 1969; Moss and Salentijn, 1971) the gonial angle was also measured (see Fig. 4). Past studies involving the gonial angle implemented standards from Riolo (1974) for comparison. However, an assumption of the present study is that different facial types grow differently, hence, more meaningful data might be brought about by comparison to a homogeneous control group rather than a normal population.

Proffit (1985) has stated in regards to skeletal vertical relationships, "To assess the skeletal situation, one must also evaluate posterior vertical dimensions". The PM (posterior maxillary) as compared with ramus/MCF (middle cranial fossa) vertical dimensions is a measurement in Enlow's Counterpart

Figure 4. Variable #8. Gonial angle alignment.



Analysis. It is an indication of the relative height of the posterior nasomaxillary complex. This variable was done by hand. An individual with a long PM will tend to have a relatively long midface whereas an individual with a short PM will tend to have a short midface. This measurement is done by first comparing the MCF and PM relative alignment (see Fig. 5). The neutral MCF/PM alignment (dashed line), which has an internal angle of 40.3°, is compared to the patient's MCF/PM alignment (solid line). The neutral MCF/PM alignment is drawn first using a preconstructed template which has a 40.3° internal angle. The template is used by: (1) measuring the length of the MCF, and (2) transferring this length to the corresponding line on the template (with the vertex representing SE). (3) Place the tracing of the subject over the template superimposing on Ar and orienting the PM vertical of the patient and the neutral PM parallel to each other. (4) Draw the neutral MCF/PM alignment with a dashed line on the tracing. The second part of this measurement involves the alignment of the patient's ramus plane and its relationship to the neutral ramus plane. A line from Ar to Go represents to individual's ramus plane. The neutral ramus plane is represented by a line from Ar to the midpoint between Ar and the neutral PM vertical at the level of Go. When the MCF rotates forward or backward, and the ramus rotates the same amount in the corresponding direction, no vertical disproportion in PM dimension

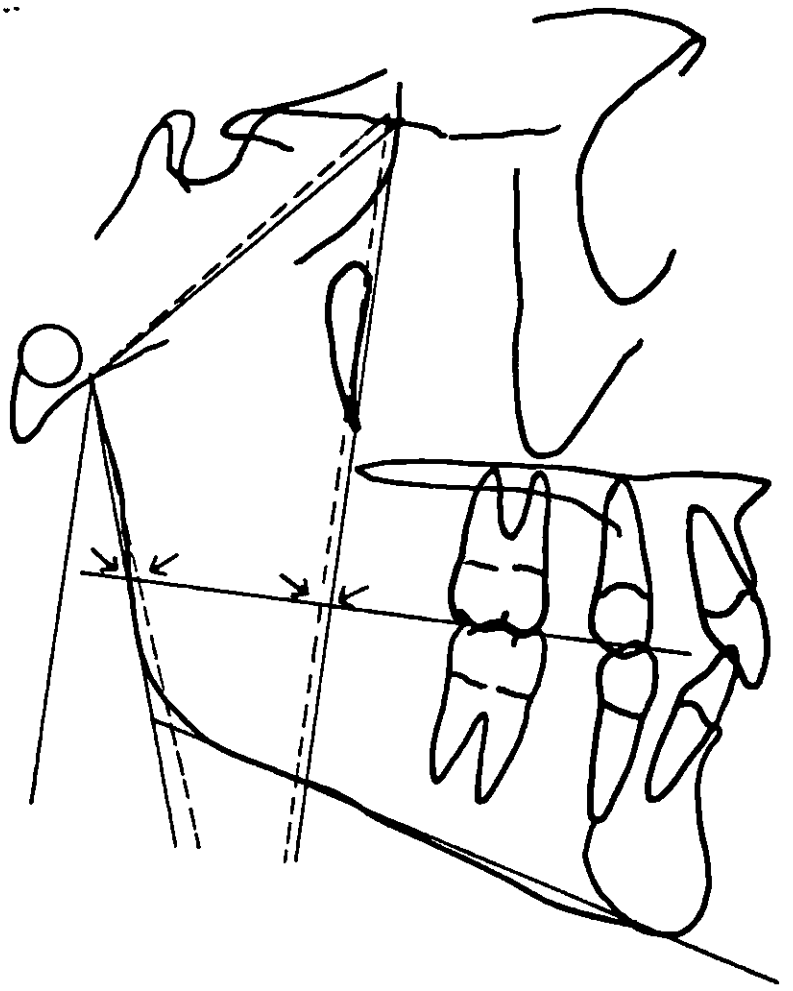
has occurred relative to the composite vertical dimension of the middle cranial fossa and the ramus. The MCF rotation is determined by measuring the difference between PM and neutral PM along FOP. If PM is ahead of neutral PM, the MCF has a downward and forward rotation and is recorded as a positive value. If the PM is behind the neutral PM, the MCF has an upward and backward rotation and is recorded as a negative value. The ramus rotation is determined by measuring the difference between the point of intersection between Ar-Go and the FOP and the neutral ramus (NRa) along the FOP. If this posterior aspect of the ramus is ahead of the NRa then the ramus has a forward rotation and is recorded as a negative value. If the posterior aspect of the ramus is behind NRa then the ramus has a backwards rotation and is recorded as a positive value. Positive rotations of the MCF and the ramus will cause a "long" PM to occur. Negative rotations will cause a "short" PM to occur. (Ethnic variations and populations tendencies were not considered in this study).

Net directional changes for each variable were determined between T1 and T2, the treatment interval, and are summarized on Table V. The control variables were assessed in a similar manner.

Statistical Methods

Data analysis was performed utilizing the Statistical Package for the Social Sciences (SPSS) which was available on the DEC System- 2060 TOPS- 20 at the Jennings Computer Center facility in

Figure 5. Variable #9. PM as compared with ramus/MCF vertical dimensions. (See text for details.).



Case Western Reserve University's Medical School. Statistical evaluation was done in consultation with Donna McClish, Ph.D., who assisted in planning and interpreting the appropriate analyses.

Descriptive statistics were first run on all the variables in both experimental and control groups to check the data generated.

One major goal of this study was to examine the effect of facial type, if any, on treatment response when orthodontically correcting an excessive overbite. A second objective was to evaluate which particular variables have a treatment effect when examining different facial types. Accordingly, after descriptive statistics for each facial type in the control and treatment group were run, treatment differences were assessed by a two-way analysis of variance (ANOVA). Three significant interactions occurred which required further tests to investigate the different effects of these variables. A one-way ANOVA was then run to examine differences between facial types on these variables, and T-tests were utilized to compare the differences between the treated and control group within each facial type.

The two-way ANOVA was also used to examine growth differences among varying facial types. Similar analyses were used to examine the effect of sex on treatment response.

A one-way ANOVA was used to examine extraction and nonextraction cases, patients treated by different techniques, and patients treated with different auxillaries, however, sample

distribution was not even among different groups and sample size was often too small in many of the groups to make valid comparisons.

Error Study

Digitization error was assessed by redigitizing the tracings of 10 patients. Intra-investigator tracing error was assessed by retracing 20 patients who were chosen at random. Paired t-tests and a coefficient of linear correlation was calculated between the first and second determination of each dimension. The square of the coefficient, r_{xx}^2, estimates the reliability of each variable and is an estimate of "... the proportion of their variance that is true variance" (Guilford, 1973; Hans, 1981).

RESULTS

Descriptive statistics on all the variables in both experimental and control groups permitted an initial examination of the data to check for any errant measurements. All data appeared to be within acceptable ranges looking at each experimental and control group individually as well as comparing them to each other.

The reliability coefficients assessing digitization and tracing error are presented in Tables III and IV., respectively. The higher the value of r, the more accurately the point was located upon redigitization or upon retracing. A r value of 1 is a perfect correlation and would indicate that points were located in the exact position on both trials. No significant tracing errors were found upon a paired t-test.

The results of this study will be presented in two sections. The first section will examine the morphological changes experienced by facial type with and without treatment. The second section will evaluate variables that had a treatment effect when comparing different facial types.

Effects of Facial Type

Two variables, BLI and MNSK, were significant ($p < .05$) across all facial types and in both the treated and the control groups (see Tables VI and VII). MNSK increased as the face became more leptoprosopic. In the control population, vertical drift of

TABLE III

RELIABILITY COEFFICIENTS (ASSESSING DIGITIZATION ERROR)

Measure	r	r^2
MXSK	.951	.903
BUI	.936	.876
TUI	.983	.966
TLI	.972	.944
BLI	.979	.958
MNSK	.997	.994
OB	.951	.905
GO	.969	.939

TABLE IV

RELIABILITY COEFFICIENTS (ASSESSING TRACING ERROR)

Measure	r	r^2
MXSK	.769	.591
BUI	.883	.780
TUI	.940	.883
TLI	.777	.604
BLI	.876	.767
MNSK	.869	.755
OB	.951	.904
GO	.796	.63

the mandibular incisor (BLI) also increased as faces became more leptoprosopic. Without looking at growth, the treated sample experienced increased "intrusion" as the facial type became more leptoprosopic, however, the overall response when controlling for growth was less "intrusion" as faces became longer and narrower.

MXSK, BUI, and TLI were variables that were accompanied by significant interactions (see Tables VI, VII, and VIII). There was a significant difference ($p < .05$) in MXSK between the meso- and euryprosopic control groups. Without treatment, all facial types experienced normal downward deposition, resorption and primary displacement of the bony maxillary arch and palate. In this study, the parts of the maxilla grew down significantly more in the euryprosopic group than the mesoprosopic group. There was no significant differences in the treated group on the variable MXSK. No significant differences were found among facial types on the vertical drift of the maxillary incisors in the control group. When treated, BUI was significant ($p < .05$) between eury- vs. lepto- and lepto- vs. mesoprosopic facial types. The response of all facial types when treated was relative maxillary incisor intrusion, however, the response was seen the most in the mesoprosopic facial type and the least in the leptoprosopic facial type. TLI remained fairly constant in the control group. A one-way ANOVA showed no significant differences between facial types. When treated, however, TLI was significant ($p < .05$) between the

TABLE V

SUMMARY OF SIGN CONVENTIONS

Overall: Positive values tend to decrease overbite and are associated with favorable responses. Negative values tend to increase overbite and are associated with unfavorable responses.

Variable # 1- MXSK
+ = upward movement of anterior aspect of maxilla
- = downward movement of anterior aspect of maxilla

Variable # 2- BUI
+ = upper incisor intrusion
- = upper incisor extrusion

Variable # 3- TUI
+ = labial tipping of upper incisor
- = uprighting of upper incisor

Variable # 4- TLI
+ = labial tipping of lower incisor
- = uprighting of lower incisor

Variable # 5- BLI
+ = lower incisor intrusion
- = lower incisor extrusion

Variable # 6- MNSK
+ = downward movement of anterior aspect of mandible
- = upward movement of anterior aspect of mandible

Variable # 7- OB
+ = overbite decreased
- = overbite increased

Variable # 8- GO
+ = gonial angle became more obtruse
- = gonial angle became more acute

Variable # 9- PMV
+ = PM vertical became longer
- = PM vertical became shorter

TABLE VI

DESCRIPTIVE STATISTICS

Means and Standard Error of the Means Comparing Facial Type with Treatment (in mm)

		Euryprosopic		Mesoprosopic		Leptoprosopic	
		Mean	SEM	Mean	SEM	Mean	SEM
MXSK	Control	-2.32	0.58	-0.91	0.29	-1.74	0.32
	Exp.	-1.43	0.45	-2.41	0.37	-1.90	0.42
BUI	Control	-0.87	0.28	-1.39	0.11	-1.19	0.21
	Exp.	0.17	0.34	0.42	0.26	-0.76	0.31
TUI	Control	-0.05	0.16	0.08	0.08	0.002	0.09
	Exp.	-0.69	0.37	-0.75	0.25	-0.65	0.17
TLI	Control	-0.004	0.24	-0.08	0.10	0.08	0.10
	Exp.	0.65	0.28	0.03	0.16	1.07	0.24
BLI	Control	-2.03	0.47	-2.58	0.20	-2.67	0.29
	Exp.	0.68	0.44	-0.86	0.39	-1.49	0.35
MNSK	Control	3.51	0.46	4.16	0.28	4.45	0.45
	Exp.	3.46	0.50	5.01	0.54	5.64	0.54
OB	Control	0.56	0.34	0.18	0.13	0.67	0.15
	Exp.	4.30	0.31	3.83	0.31	3.80	0.31
*GO	Control	-2.60	0.69	-1.83	0.38	-1.94	0.39
	Exp.	-1.20	0.42	-1.80	0.51	-0.86	0.49
PMV	Control	0.09	0.39	0.002	0.21	0.10	0.24
	Exp.	0.19	0.17	0.93	0.40	0.90	0.30

*in degrees

TABLE VII

P-VALUES FOR TWO-WAY ANOVA

	Treatment	Facial Type	Interactions
MXSK	.4601	.8555	* .0194
BUI	.0000	.0439	* .0117
TUI	* .0001	.9809	.8616
TLI	.0005	.0017	* .0300
BLI	* .0000	* .0034	.1804
MNSK	.1244	* .0270	.5631
OB	* .0000	.3503	.4717
GO	* .0487	.5457	.3238
PMV	* .0248	.5696	.4873

*Significant

TABLE VIII

P-Values from T-Tests Comparing Means Across Facial Types (Separate for Treated and Control Groups) where Interactions Occurred

		Eury vs. Lepto	Lepto vs. Meso	Meso vs. Eury
MXSK	Control	0.3910	0.0577	* 0.0351
	Treated	0.4386	0.3586	0.0985
BUI	Control	0.3600	0.3785	0.1332
	Treated	* 0.0376	* 0.0047	0.5703
TLI	Control	0.7220	0.3052	0.7514
	Treated	0.2107	* 0.0008	† 0.0523

† Marginally Significant

* Significant

TABLE IX

P-Values from T-Tests Comparing the Treated and Control Groups Where Interactions Occurred

	Euryprosopic	Mesoprosopic	Leptoprosopic
MXSK	0.2715	* 0.0017	0.7664
BUI	0.0729	** 0.	0.2465
TLI	0.1607	0.5798	* 0.0006

*Significant

**$p < 0.00001$

lepto- vs. mesoprosopic group and marginally significant between the meso- vs. euryprosopic group. The leptoprosopic sample responded with the greatest amount of mandibular incisor tipping while the mandibular incisor in the mesoprosopic sample revealed a tendency toward tipping but did not change much from the control group.

Effects of Treatment

Five variables were significantly affected by treatment and had no interactions (see Table VII). They were TUI ($p < .001$), BLI ($p < .001$), OB ($p < .001$), GO ($p < .05$), and PMV ($p < .05$). Further characterization of the significant treatment effects included uprighting of the maxillary incisor, relative intrusion of the mandibular incisor, excessive overbite correction, gonial angles that became less acute, and PM verticals that became longer.

Three other variables, MXSK, BUI, and TLI were accompanied by significant interactions (see Tables VII, VIII and IX). MXSK was significant ($p < .01$) only in the treatment of mesoprosopic facial types where treatment brought the maxillary arch down further than that seen in growth alone. BUI was significant ($p < .05$) in the treatment of mesoprosopic individuals where the greatest amount of maxillary incisor intrusion occurred. TLI was significant ($p < .001$) in leptoprosopic individuals.

DISCUSSION

The purpose of the present study was to evaluate the influence of facial type on the nature of the contributions from treatment and growth to the orthodontic correction of an excessive overbite. Accordingly, individual measurements of tooth movement, skeletal changes, and growth were taken and analyzed within a given facial type as well as among varying facial types. The statistical analysis employed was the two-way ANOVA. The advantage of using a two-way ANOVA is that one can examine the effects of each variable after controlling for the effects of the other variable. The influence of facial type was tested on each parameter after controlling for the effect of treatment. The effect of treatment was tested on each parameter after controlling for the influence of facial type. A two-way ANOVA can also test for the presence of interaction effects. The definition of an interaction effect is where the effect of one variable depends on the level of the other variable (Rosner, 1986). This tested whether or not there was a differential effect among different facial types. For example, treatment may only have had an effect of tipping the mandibular incisor in leptoprosopic facial types. Significance was assumed across all facial types or within all facial types where there was no interaction effect.

Orthodontists use the vertical dimension in diagnosing and treatment planning individuals with excessive overbites. The

present study, however, did not take treatment objectives into account. Therefore, the success of attaining treatment goals was not measured, rather, this study reflects the final outcome, the results achieved when orthodontically treating patients with excessive overbites.

The present study did not select patients who were treated by a specific orthodontic technique. The intent was to examine many different treatments in order to randomize treatment and essentially remove it as a factor. Evaluation of the sample, however, revealed that close to 90 percent of the treated sample underwent extractions as part of their treatment. The results of this study, therefore, do not only reflect the influence of facial type but also the influence of extracting when orthodontically correcting excessive overbites.

It should be noted again that the treated and control groups were compared using mean ages. Comparisons based on mean ages would tend to have more variability than comparisons based on matched samples.

The reliability coefficient is an estimate of the proportion of variance that is true variance. From the results on Table IV, therefore, caution must be exercised when interpreting the results of this study. Although there were no significant differences pertaining to tracing error on t-tests, the reliability coefficients would tend to suggest that some of the variability

analyzed in the present study was due to tracing error.

This discussion will be divided into two sections. The first section will evaluate the mean changes from T1 to T2 in the treated group and C1 to C2 in the control group. Also, the effect of treatment when controlling for growth will be examined. The second section will evaluate the percentage contribution of each variable to the overall result within each facial type. General tendencies as well as specific findings will be explored.

Mean Changes and Treatment Effects

The vertical change seen in the maxilla of the control group in euryprosopic individuals is an unexpected observation (see Table VI, Fig. 6). It shows that left untreated, euryprosopic faces experienced the most downward change of the bony maxilla of all the facial types. It was significantly greater when compared to mesoprosopic faces. This is in disagreement with Creekmore (1967) who found that shorter faces were less susceptible to vertical increases, and also Richardson (1969) who did not find any significant difference in midfacial height between deep and open bite subjects. Richardson, however, also observed that the deep bite sample in the age range of 7 to 10 years of age had a longer midface (Nasion-ANS) than an open bite sample of similar age. This relationship reversed itself with age so as the deep bite group became older, 15 to 27 years of age, the midface became shorter in comparison to the open bite group. The midface in

Figure 6. Bar graph depicting the mean and standard error of the mean for Variable #1, MXSK, and Variable #2, BUI, for each facial type. The treated sample is represented by bars on the left while the corresponding control sample is represented by bars on the right.

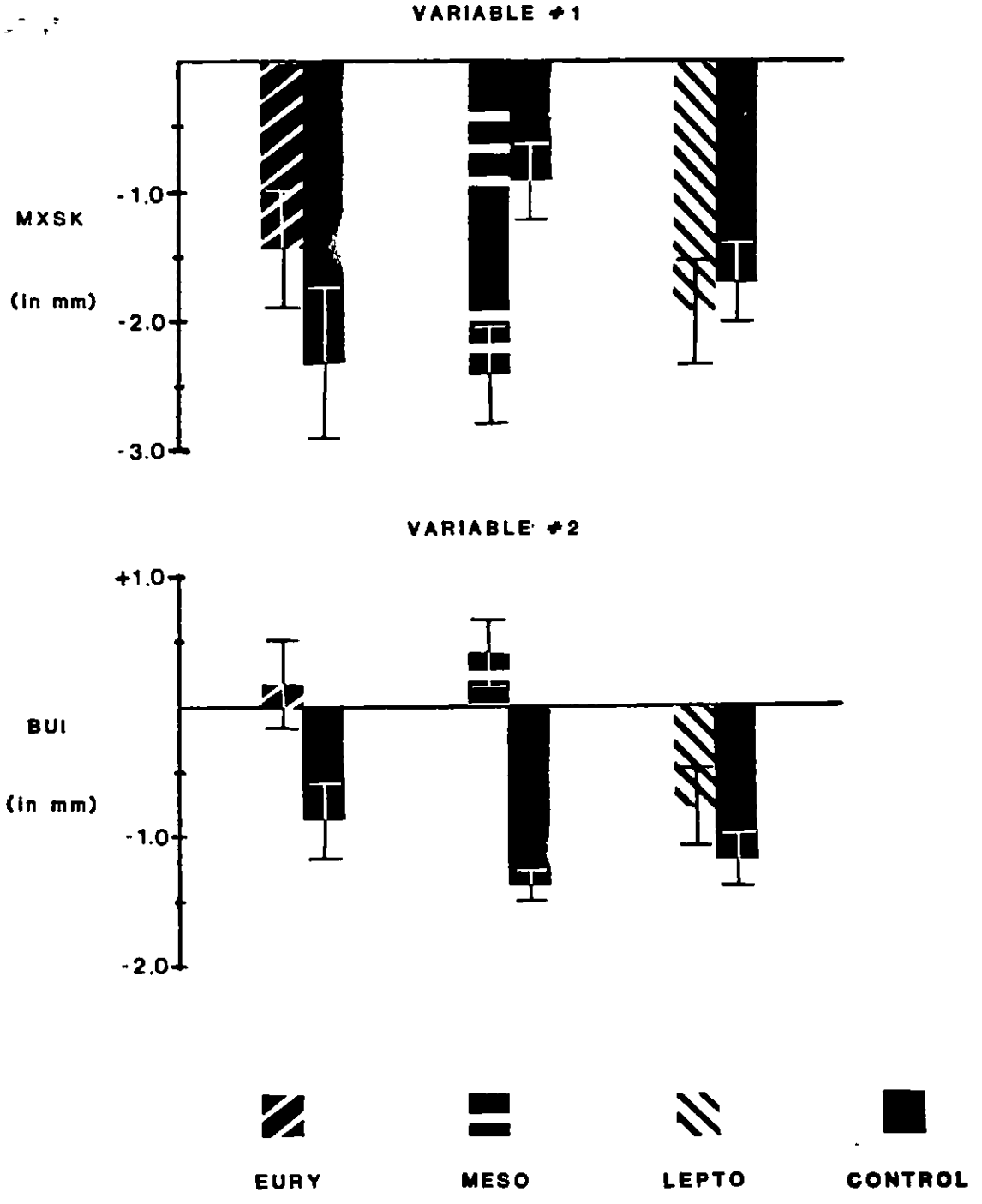

VARIABLE #1
MXSK
(in mm)
-1.0
-2.0
-3.0
VARIABLE #2
BUI
(in mm)
+1.0
-1.0
-2.0
EURY
MESO
LEPTO
CONTROL

Figure 7. Bar graph depicting the mean and standard error of the mean for Variable #3, TUI, and Variable #4, TLI, for each facial type.

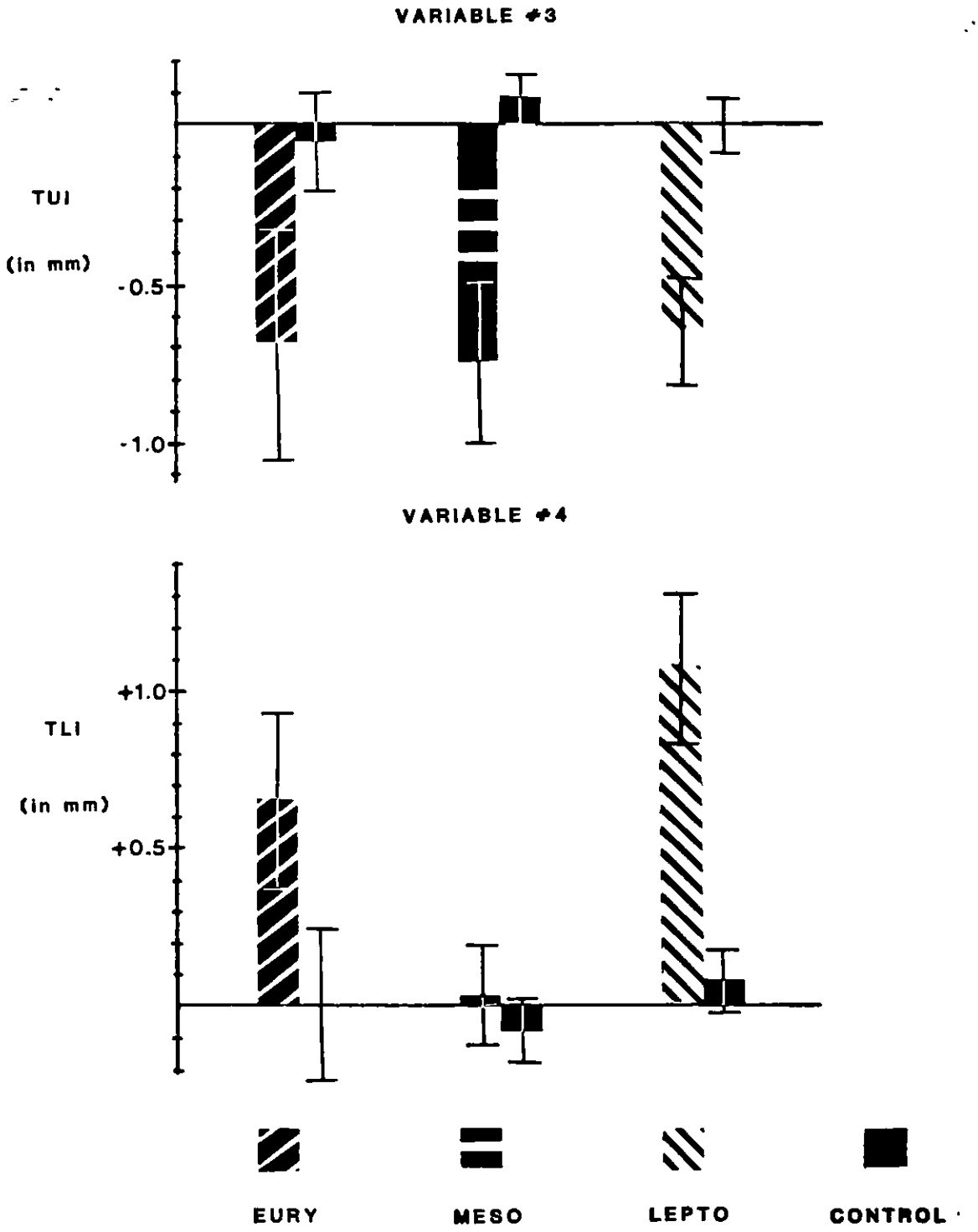

VARIABLE #3
TUI
(in mm)
-0.5
-1.0
VARIABLE #4
TLI
(in mm)
+1.0
+0.5
EURY
MESO
LEPTO
CONTROL

Figure 8. Bar graph depicting the mean and standard error of the mean for Variable #5, BLI, and Variable #6, MNSK, for each facial type.

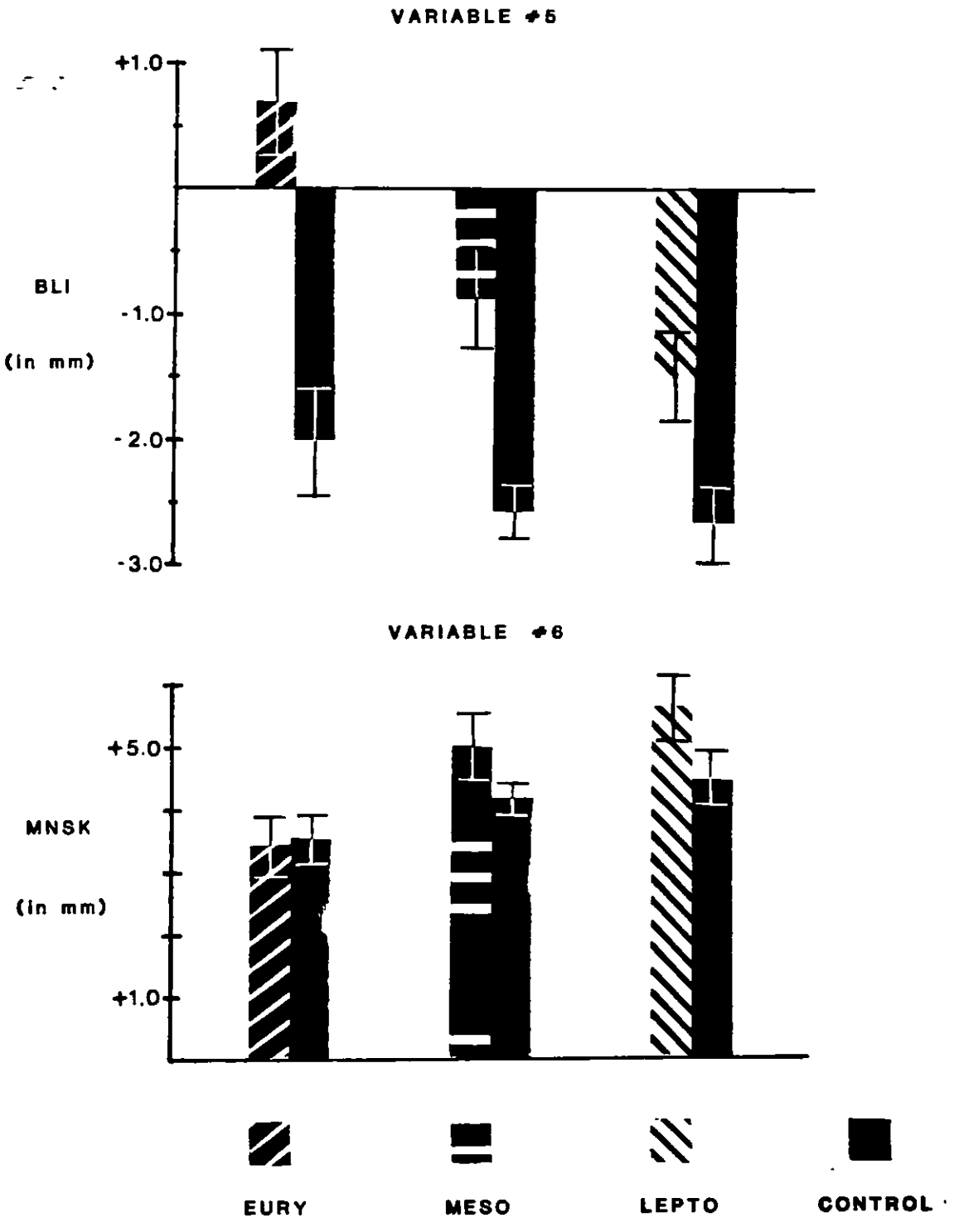

VARIABLE #5
+1.0
BLI
(in mm)
-1.0
-2.0
-3.0
VARIABLE #6
+5.0
MNSK
(in mm)
+1.0
EURY
MESO
LEPTO
CONTROL

Figure 9. Bar graph depicting the mean and standard error of the mean for Variable #7, OB, and Variable #8, GO, for each facial type. GO is the only angular measurement and, therefore, its changes are in degrees.

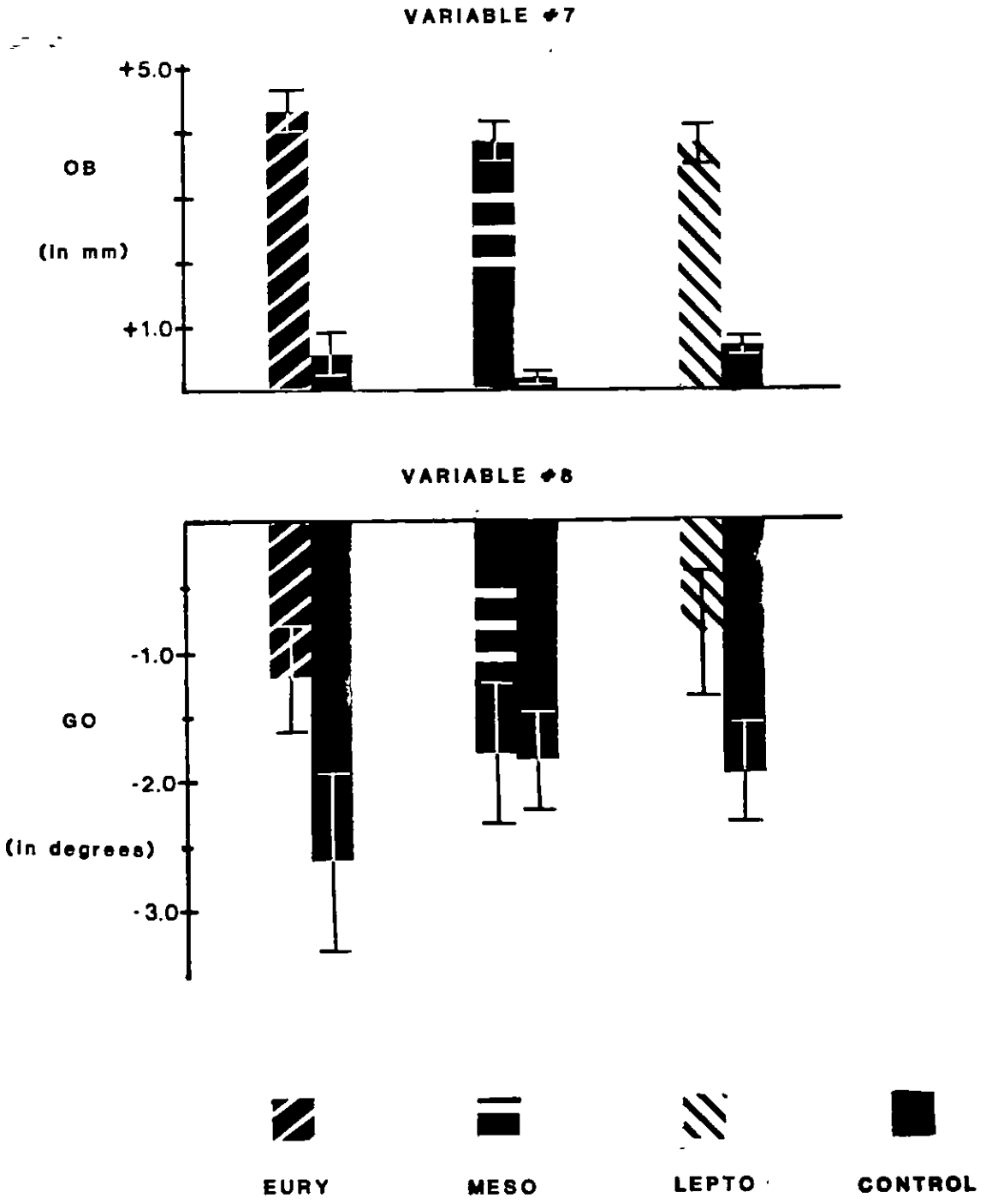
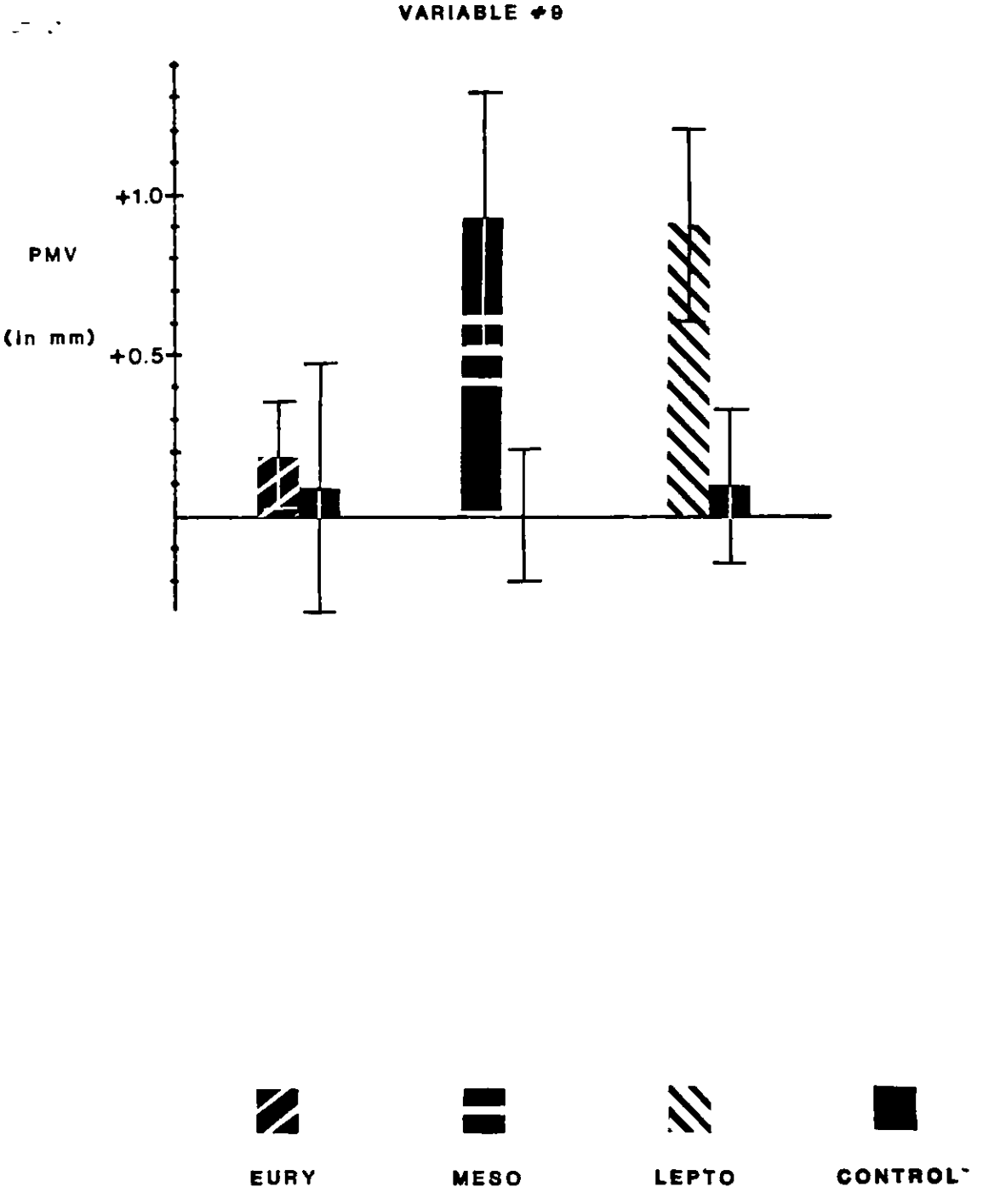

VARIABLE #7
+5.0
OB
(In mm)
+1.0
VARIABLE #8
-1.0
GO
-2.0
(In degrees)
-3.0
EURY
MESO
LEPTO
CONTROL

Figure 10. Bar graph depicting Variable #9, the PM as compared with ramus/MCF vertical dimensions for each facial type.


VARIABLE #8
+1.0
PMV
(In mm)
+0.5
EURY
MESO
LEPTO
CONTROL

Richardson's deep bite subjects in the 11 to 14 year old range was 0.65 mm greater than his open bite sample. If skeletal structures in open bite subjects are comparable to leptoprosopic facial types the euryprosopic group in this study had a lower midface that was 0.58 mm greater than the leptoprosopic group. These differences were not significant in both studies.

The expectation for vertical maxillary remodeling and displacement was for it to be similar across facial types or increase as facial types became longer. What occurred was the facial type that had the supposedly lowest potential of vertical development had the most downward change of the maxilla with intermediate facial types exhibiting the least. One possibility was that differences between sex could have affected MXSK. This might have been likely had males been the predominate sex, however, the sample distribution was actually weighted for females. A three-way ANOVA between treatment, facial type and sex was subsequently run and did not reveal any significant results. A second possibility is that the euryprosopic control group may not have had a normal distribution due to a small sample size. A few extreme measurements in a sample of 11 could have affected the mean change observed. Another possibility is that MXSK had the lowest reliability coefficient when assessing tracing error. Thus, the changes observed during growth might have been due to more of a technical origin than a biological origin. A fourth

possibility is related to Montague's categories of facial type. The present study separated groups into three facial types while Montague separated groups into five facial types. The morphologic change observed in MXSK may have been obscured by studying hypereury- and euryprosopic facial types together. Lastly, perhaps it is an incorrect assumption that eury- and leptoprosopic facial types should have the least and greatest magnitudes of change, respectively on all variables reflecting growth. It may be possible that greater amounts of lower midfacial height are necessary in euryprosopic types in order to have an upper facial height that has been observed to be similar between deformities (Ellis, 1984). Bishara (1985), in his longitudinal study of different facial types, found a tendency of midfacial height (N-ANS) to decrease as faces become shorter. His sample, however, consisted of persons with normal occlusion and skeletal relationships and facial types were classified according to the ratio of the posterior to the anterior face heights (S-Go/N-Me) and the Frankfort horizontal mandibular plane angle.

Treatment effects of MXSK can be interpreted in light of orthodontic auxillaries used. Euryprosopic facial types most often had high pull headgear (HPHG) with J-hooks to retract cuspids or intrude incisors or cervical pull headgear (CPHG) to extrude molars. A concomitant effect could have been to hold the maxilla from its normal extent of downward growth. What is

interesting is that if CPHG was used for "molar extrusion" in an euryprosopic individual, what might have actually occurred is an upward rotation of the maxilla since no change was seen in MNSK to indicate an increase in mandibular skeletal or dental height. The type of headgear usually implemented in the treatment of a leptoprosopic individual is a HPHG with J-hooks to intrude incisors or retract cuspids or a high pull facebow (HPFB) to hold the maxilla from its downward, forward growth. A 0.2 mm difference from the control to the treated sample may substantiate headgear benefit in a group that may be more susceptible to greater vertical development and change. Mesoprosopic individuals are probably the least likely group to receive headgear therapy and in this study were the most significantly affected in maxillary change when treated. The most likely factor involved in bringing the maxilla further down than what was seen by growth alone was the use of Class II elastics.

Mesoprosopic facial types experienced the most maxillary incisor drift during growth (1.4 mm), however, they also achieved the most intrusion during treatment (1.8 mm)(see Table VI, Fig. 6). While there was a significant difference in the treated sample between eury- and lepto-, and meso- and leptoprosopic facial types, treatment effect on BUI was significant only is the mesoprosopic group. Burstone (1977) reported that incisor intrusion is desirable in patients with high mandibular planes

because molar extrusion to correct the deep bite would lengthen an already longer than average face and also make Class II molar correction more difficult is that was the pre-existing malocclusion. However, in this sample, intrusion was least where it would seem to be the most desirable. Leptoprosopic facial types had a mean maxillary incisor intrusion of 0.4 mm compared to 1.0 mm for eury- and 1.8 mm for mesoprosopic facial types. Does a 0.4 mm intrusion of maxillary incisors suggest a limitation due to facial type? Examination of the untreated control group shows no significant differences between facial types, i.e. one is not associated with significantly more or less growth in respect or vertical drift of the maxillary incisors to be able to consider growth as a limiting factor in leptoprosopic individuals. Also, mesoprosopic subjects had the most vertical drift of the maxillary incisor and subsequent intrusion of all the facial types.

The means seem to indicate a compensatory relationship between downward growth of the maxilla or lower midface and of incisal vertical drift in the control group. Where there is more downward change of MXSK, there is also less vertical drift of the maxillary incisor and vice versa. Thus, the group characterized by the most lower midfacial growth (eury-) also had the least incisal vertical drift, and the group that had the least lower midfacial growth (meso-) had the most incisal vertical drift. It is difficult to assess why one of the extreme movements such as

vertical drift occurred in intermediate facial types. Perhaps, it is incorrect to assume that extreme movements occur only in extreme facial patterns. The compensatory growth mechanisms that act and interact to form a balanced composite of facial form and structure are indeed complex, and the limitation of the variables used in this study may not allow a precise picture to emerge since the majority of these parameters considered dimensions of a vertical nature in the anterior region only.

There was no difference among facial type and tipping movement of the maxillary incisor (see Table VI, Fig. 7). All had minimal change with growth. All had similar uprighting as a treatment effect. This would tend to be in disagreement with Steadman (1949) and Schudy (1963, 1968) who believed a high interincisal angle was responsible for a deep overbite. Patients in this sample probably began with incisors that were more labially flared and thus had to be uprighted to some extent by treatment. This also reflects a sample that consisted primarily of patients treated by extraction.

Tipping movement of the mandibular incisor did not change significantly with growth in any facial type (see Table VI, Fig. 7). The tendency was for the incisors to tip lingually with growth in the eury- and mesoprosopic group, which is consistent with findings from Enlow (1982). However, leptoprosopic facial types tended to have mandibular incisors that proclined with

growth. The only significant treatment effect seen was in the leptoprosopic group where tip caused a favorable 1.0 mm change in overbite. Tip of the mandibular incisor in the euryprosopic sample caused a 0.65 mm decrease in overbite which was not statistically significant ($p = .16$). Other investigators have reported tipping of the mandibular incisor, however, they were in patients with low mandibular plane angles or more "brachyfacial" patterns (Dake, 1986; Engel, 1980). Otto (1980) examined incisor intrusion in different facial types and found tipping to be one component of overbite correction. No figures were stated, however, to distinguish the amount of tip seen in the various facial patterns.

Several reasons are possible as to why leptoprosopic patterns had the most tipping of the incisor. One possibility is that symphyseal morphology in "dolicofacial" patterns are more narrow, thus limiting the amount of incisor intrusion (Ricketts, 1964; Bench et al. 1978). Another possibility is that intrusion is limited by the vertical drift that occurs normally by growth. Enlow (1982) noted in regards to vertical drift of the lower incisor that "the amount can vary among individuals having different facial types". This study substantiates the tendency for longer and narrower faces to have more vertical drift of the lower incisor associated with it. The differences among facial types were significant. If there is a limit due to symphyseal

morphology or growth, perhaps once this has been reached, forces directed apically and also at a point labially to the center of resistance will now tip the tooth instead of intruding it, especially on round wire. A second possibility is that leptoprosopic facial types have more of a Class II tendency due to a longer midface causing the mandible to rotate clockwise and thus become more retrusive (Enlow, 1982). The tip of the incisor in this instance may reflect the need to correct the overjet and to attain satisfactory incisal contact. The third possibility relates to the airway. Lundstrom and Woodside (1983) found that in their untreated vertically developing cases the mandibular incisors tended to procline with age while in horizontal cases they became more retroclined. They found that vertically growing cases showed a degree of nasal obstruction. Possibly, the leptoprosopic patient who might also be characterized as having a narrower ramus and shorter corpus length along with a retrusive mandible may be posturing the tongue forward in an effort to gain airway space, which may have an effect of tipping the incisor.

The results of mandibular incisor intrusion (BLI) do not coincide with Otto (1980) who found no significant difference in the amount of intrusion attained in brachy- and dolicofacial patterns. In contrast, this study found intrusion to decrease as the face became longer (see Table VI, Fig. 8). Otto's results may be somewhat inconclusive since he did not have a statistically

adequate sample of dolicofacial patterns in his study.

The results indicate that different facial types grow and respond differently in terms of anterior mandibular skeletal change (see Table VI, Fig. 8). Increased vertical changes were found in facial types that were longer and narrower. Previously, a compensatory relationship was described between MXSK and BUI that was unexpected but consistent within this study. The results from the control group MNSK and BLI, however, are what may be expected from faces that are short compared to faces that are long. Both variables revealed increases in vertical growth as the facial type became more leptoprosopic.

No significant treatment effect was seen in MNSK in any facial type. The tendency observed, however, was to see increases with treatment as faces became longer. Two totally different implications exist as a result of MNSK not being a significant treatment effect in leptoprosopic individuals. One is that the vertical dimension was controlled successfully by the use of headgear, minimal use of intermaxillary elastics, or other methods related to treatment philosophy. If these auxillaries or technical methods were no longer employed, significant and possibly detrimental changes could have resulted. The other implication is that MNSK may not have significantly changed regardless of whether auxillaries were used or not, that is, vertical control for MNSK may be unnecessary. Investigators have

both advocated molar extrusion and disapproved of incisor intrusion (Schudy, 1966) and disapproved of molar extrusion and advocated incisor intrusion (Ricketts, 1960) under the assumption that selective and isolated tooth movements can be orthodontically accomplished. Perhaps, practitioners believe they have more control than they actually do when, in reality, growth within a particular facial pattern is the final determinant. These implications may be examined further in a study possibly involving only Begg treated patients. Because the pure Begg technique does not involve headgear but utilizes "anchorage bends" to intrude incisors and intermaxillary elastics to correct horizontal discrepancies in every facial type, insight into these two opposing ideas may be gained.

It is interesting that although the orthodontic result was not a criterion for selection, overbite correction was highly significant (see Table VI, Fig. 9). Orthodontics is very successful in correcting a problem that was described as "the most difficult problem in orthodontia" (Grieve, 1928).

The findings from the untreated control group support the results of past studies that have shown overbite to decrease with age (Bjork, 1953; Baume, 1950; Moorrees, 1959). It is difficult to determine what factors cause the decrease in overbite. It seems unlikely that overbite should have improved with age at all without treatment. This study found gonial angle to decrease with

age. The PM vertical did not compensate and remained relatively unchanged. Taking into account the downward remodeling and displacement of the maxilla and the extent of vertical drift of the incisors makes this phenomenon of a decrease in overbite with age difficult to evaluate. Relative incremental growth changes are probably a factor since euryprosopic facial types who had the most downward change of the maxilla and most closure of the gonial angle, also had the least amount of vertical drift of the incisors. In contrast, the leptoprosopic group had a lesser amount of downward change of the maxilla and lesser closure of the gonial angle but had more vertical drift of the incisors.

Decreases in gonial angle with age, as already noted, are consistent with findings from Richardson (1969) and Lundstrom and Woodside (1983). Although no significant differences among facial type were found in the control group, euryprosopic individuals tended to have the most closure of the gonial angle with age (2.6 degrees) while meso- and leptoprosopic subjects were similar with closures of 1.8 and 1.9 degrees, respectively (see Table VI, X, Fig. 9). With treatment, the gonial angle in the eury- and leptoprosopic group did not close to the extent it did by growth alone. Trouten (1980) found his deep bite sample to have no change in the gonial angle from pre-treatment to deband. He differentiated his deep bite sample on the basis of being skeletal Class I or Class II, not on the basis of facial type. It is

TABLE X

Mean Change Between Treated and Control Group ($X_{Treated} - X_{Control}$) Representing the Effect of Treatment Controlling for Growth (in mm).

	Euryprosopic	Mesoprosopic	Leptoprosopic
MXSK	0.9	- 1.5	- 0.2
BUI	1.0	1.8	0.4
TUI	- 0.6	- 0.8	- 0.7
TLI	0.6	0.1	1.0
BLI	2.7	1.7	1.2
MNSK	- 0.1	0.8	1.2
OB	3.7	3.6	3.1
*GO	1.4	0.0	1.1
PMV	0.1	0.9	0.8

*in degrees

possible that his sample consisted mainly of intermediate facial types who, in this study, also did not change with respect to gonial angle. What may be occurring in euryprosopic individuals is that the whole mandible may be rotating upward due to a relatively shorter midface as well as inferior drift of the posterior teeth that, together, are allowing the mandibular corpus to rotate downward to some extent to compensate. MNSK became slightly smaller in the euryprosopic group and may reflect posterior inferior drift. Leptoprosopic individuals may be experiencing ramus uprighting in order to compensate for a midface that is lengthening.

PMV, though not significant between facial types followed the same pattern as MXSK (see Table VI, Fig. 6 and 10). Both variables measure the midface or some aspect of the midface. Both eury- and leptoprosopic facial types had higher amounts of MXSK and also had increased changes of PMV by growth alone. MXSK in the mesoprosopic sample, however, had the least amount of change that was also reflected in PMV. With treatment, both meso- and leptoprosopic facial types experienced a significant increase in PMV which may indicate several possibilities. The mesoprosopic sample probably experienced the most lengthening of the midface, which is consistent with MXSK and which was also significant with treatment and molar extrusion to a lesser extent. Leptoprosopic individuals, on the other hand, probably experienced some increase

in posterior naso-maxillary height and more but not significant molar extrusion. Gonial angle may have closed somewhat to accommodate a vertically lengthening midface.

Percentage Contribution to Overall Change in Overbite

This section of the discussion will refer to the pie diagrams in Figures 11,12, and 13.

General findings are that TUI is fairly constant within each facial type as an unfavorable response. This reflects the amount of uprighting that occurred as a result of orthodontic treatment. Additionally, it is shown that as faces become longer, MNSK represents a greater percentage of the overall change in overbite. This may be interpreted by saying molar extrusion probably is seen more as faces become longer, though MNSK was not significant in any facial type as a treatment effect. From absolute changes across facial types, represented by the actual means and bar graphs, it can be seen that as faces became more leptoprosopic, less lower incisor intrusion was achieved. However, when examined for the percentage change within each facial type, BLI accounted for as much correction in lepto- as in mesoprosopic individuals.

In euryprosopic facial types, BLI was the single most contributing factor to overbite correction. The literature is filled with articles that adhere to the importance of musculature in patients with short faces, low mandibular plane angles, etc. (Sassouni and Nanda, 1964; Barton, 1972; Burstone, 1977; Bench et

Figure 11. Pie diagram showing percentage contribution of each variable to overall mid- to lower anterior facial height change in euryprosopic facial types. Cross hatched areas represent negative, unfavorable responses while solid areas represent positive, favorable responses to overbite correction.

EURYPROSOPIC

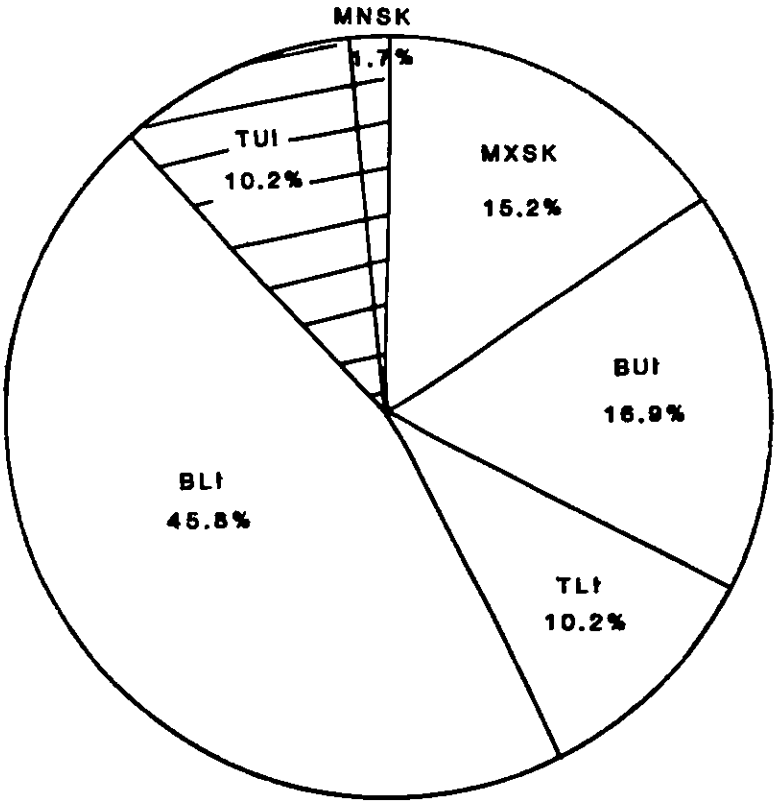


Figure 12. Pie diagram showing percentage contribution of each variable to overall mid- to lower anterior facial height change in mesoprosopic facial types. Cross hatched areas represent negative, unfavorable variables while solid areas represent positive, favorable responses to overbite correction.

MESOPROSOPIC

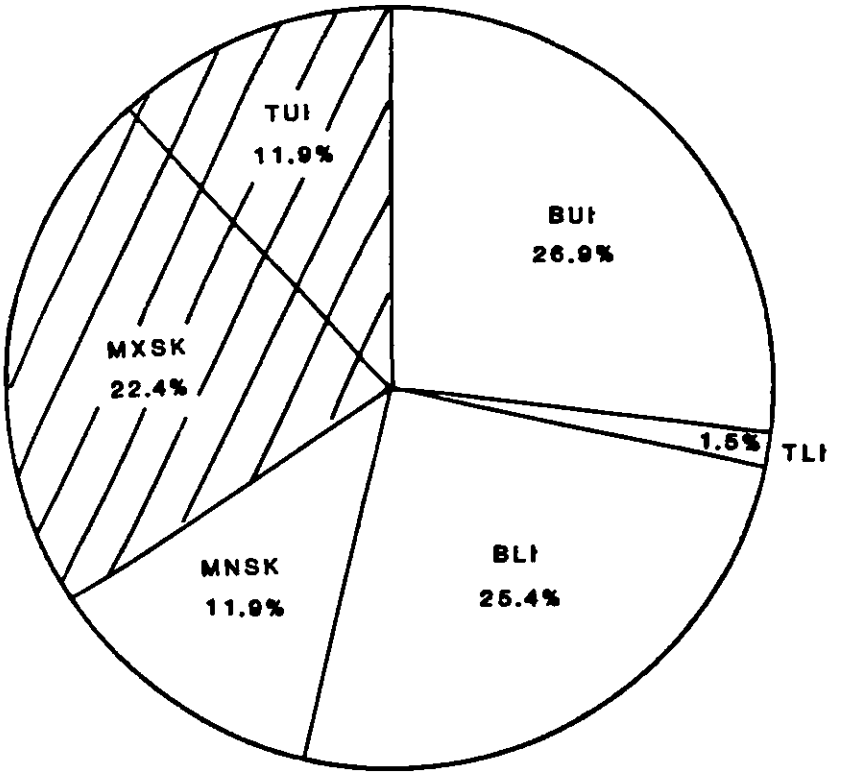
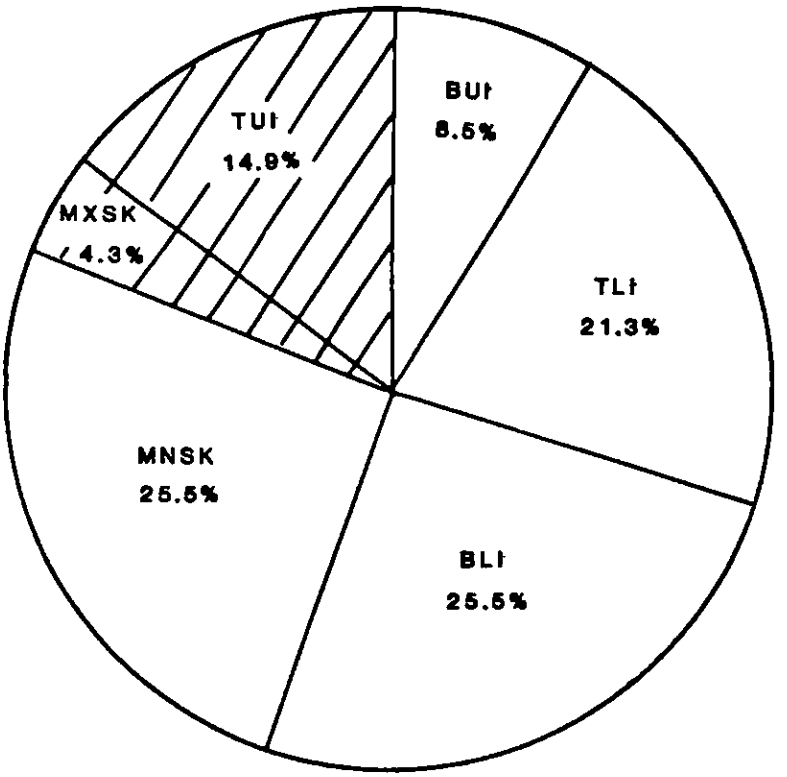


Figure 13. Pie diagram showing percentage contribution of each variable to overall mid- to lower anterior facial height change in leptoprosopic facial types. Cross hatched areas represent negative, unfavorable responses while solid areas represent positive, favorable responses to overbite correction.

LEPTOPROSOPIC



al., 1971; Engel, 1980). This study supports the premise that muscular force in these patients probably keeps the posterior teeth from extruding, allowing most of the force to be expressed as intrusion in the incisors. Favorable dental responses, not including molar extrusion, contribute about 73% of the overall changes consisting of variables BLI, TLI, and BUI. Intrusion of maxillary and mandibular incisors alone accounted for about 63% of the changes. Euryprosopic facial types were the only group to have a positive response in MXSK.

In mesoprosopic facial types, maxillary and mandibular incisor intrusion were about equal and, together, combined for over 50% of the changes seen in overbite. The effect of BUI, however, can almost be cancelled out by the downward change that occurred in the maxilla. The mean amount of midfacial downward change was 1.5 mm. If this might be a clinically undesirable response to overbite correction, headgear may be necessary in an intermediate facial type to control this. Most orthodontic philosophies and techniques ascribe to incisor intrusion as the primary source of correction in an intermediate facial type (Burstone, 1977; Bench et al., 1977; DiGiulio, 1983). Orthodontics is successful in attaining this goal since MNSK amounted to only about 12% of the overall change.

In leptoprosopic facial types, MNSK became more than double the percentage seen in mesoprosopic facial types. While this

reflects the nature of leptoprosopic individuals, the absolute increase of 1.2 mm in MNSK was not significant. Changes in the lower denture and mandible (MNSK, BLI, and TLI) amounted to about 72% of the overall changes observed.

SUMMARY AND CONCLUSIONS

The purpose of this study was to determine the effect of facial type on treatment response when orthodontically correcting an excessive overbite. The treated sample consisted of 94 patients who had an initial excessive overbite where the mandibular incisor was beyond the cingulum of the maxillary incisor. This was determined cephalometrically, however, if any questions remained, pre-treatment models were examined also. The second requirement was the availability of adequate pre-treatment and deband headfilms. Sample selection was not based on the orthodontic result since the outcome could then be biased. The control group consisted of 92 patients who met the same criteria of a deep overbite and adequate cephalograms. Both treated and control groups were divided into different facial types (eury-, meso-, and leptoprosopic) using the anthropometric classification of facial indices by Montague (1960). Because of a smaller number of euryprosopic facial types in the control group, a matched sample could not be achieved. The treated and control groups were statistically evaluated comparing mean ages. The control group was thus homogeneous with respect to having a deep bite, similar facial type, and similar mean ages. After digitization of the tracings and statistical analyses of the data, the following observations were made:

1. Extreme facial types are not always oppositely affected by treatment, nor are they completely opposite in growth.

2. Bodily movement of the maxillary incisors does not seem to be limited by growth.

3. Bodily movement of the mandibular incisor and anterior mandibular skeletal change does appear to be related to facial type. Treatment effects mirrored growth changes on these parameters.

4. Headgear appears to be an important auxillary in treating deep overbite. It altered changes in MXSK that normally occurred in growth. Headgear may be the reason why no significant treatment effect was seen in MNSK in leptoprosopic individuals.

5. Tip of the maxillary incisor was consistently an unfavorable variable and was similar in proportion to the overall changes seen among facial types. This finding reflects a sample that was primarily treated by extraction.

6. The single most contributing factor to overbite correction in euryprosopic facial types was intrusion of the mandibular incisor which accounted for close to 46% of the overall change. This study supports other findings of the unlikelihood of molar extrusion in individuals of this facial type.

7. Although mesoprosopic individuals achieved over 50% of overbite correction from intrusion of the maxillary and mandibular incisors, BUI was almost cancelled out by the response seen in MXSK. If this effect is undesirable, headgear may be necessary in intermediate facial types.

8. The parameters contributing most to overbite correction in leptoprosopic facial types is the mandibular incisor and anterior mandibular skeletal change. TLI, BLI, and MNSK contributed to about 72% of the overall change in overbite. The amount of mandibular incisor intrusion may be limited by growth.

Facial type is relevant where interactions occurred in this study and can aid in diagnosing and treatment planning excessive

overbite correction. Recommendations would include the continuation of vertical control in extreme facial patterns with more attention given to vertical control in mesoprosopic facial patterns due to the potential of an unfavorable response in the bony maxilla during treatment. More attempt can be made to increase maxillary incisor intrusion in leptoprosopic individuals since intrusion does not appear to be limited by growth in any facial type. Although significant tipping of the mandibular incisor may not be desirable in any facial type due to the instability associated with it (Simons and Joondeph, 1973) tipping may be a response observed due to the possible limitation of mandibular incisor intrusion in leptoprosopic individuals.

Differences as well as similarities exist between all facial types with respect to amount and direction of growth when considering a particular site or structure. Although growth was the factor controlled in this study, many other factors such as musculature are probably involved also.

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APPENDIX

Treated Sample- Patient Numbers

77119	78093	81033	80108
77123	78101	81048	82108
77130	79001	81076	81212
77136	79008	79096	82104
77147	79011	79091	82133
77149	79042	79089	80104
77153	79067	79078	81197
77163	79071	80066	81175
77168	79076	80078	81201
77182	79105	81070	82012
78003	80140	81114	83109
78007	79112	83024	83090
78022	79113	82024	82132
78024	79127	79013	80040
78025	79152	81154	73130
78028	79156	80065	73100
78039	79166	81075	71052
79121	80008	80012	70011
79168	80027	80133	69028
78048	80050	80084	72095
78065	80062	82109	76028
78070	80132	80116	76095
78076	81008	81109	73047
78079	80185	82107	75011
78086	80184	80031	75086

APPENDIX

Control Sample- Identification Numbers

B113	B1416	B3232	B3706
B223	B1226	B3262	B3714
B1269	B1209	B3275	
B1001	B1204	B3289	B3345
B1922	B2418	B3311	B3372
B244	B259	B261	B3375
B2328	B1895	B2739	B3380
B2702	B2007	B2768	B3381
B4323	B130	B2798	B3385
B4361	B132	B2816	B3393
B2440	B129	B2865	B3401
B3506	B2032	B2871	
B3483	B2207	B2913	B3403
B3356	B2220	B3003	B3422
B3178	B2274	B3005	B3433
B2410	B1108	B3012	B4365
B2216	B1138	B2958	B4356
B3081	B2146	B2283	B4331
B2147	B2551	B2439	B382
B2144	B2694	B3436	
B1946	B1168	B3468	
B1921	B3132	B3471	
B1916	B3207	B3508	
B1430	B3219	B3517	
B3526	B3635	B3637	

APPENDIX I

SUMMARY OF TREATED SAMPLE

Patient Number	(M/F) Sex	Facial Type	Age Start	Age Deband	(Y/N) Extraction	FMA
1	M	M	11-8	14-9	Y	23
2	M	E	12-11	16-8	Y	22
3	F	E	14-8	17-11	Y	20
4	F	E	22-5	25-9	Y	14
5	F	L	13-0	15-7	Y	30
6	M	E	11-11	14-11	Y	19
7	F	L	14-4	18-11	Y	30
8	F	E	16-2	18-11	N-	16
9	F	L	12-4	15-11	Y	29
10	M	M	14-3	16-3	Y	23.5
11	M	M	10-5	12-11	Y	22
12	M	M	11-11	14-4	Y	26.5
13	M	L	11-3	13-4	Y	35.5
14	F	M	13-4	15-11	Y	22
15	F	L	12-11	16-3	Y	31
16	M	L	12-8	14-1	Y	31
17	M	M	12-6	15-1	Y	21
18	F	M	13-2	16-7	Y	24
19	F	M	12-11	16-4	Y	25
20	M	L	13-8	17-10	Y	30
21	M	M	12-3	15-11	Y	25
22	M	M	13-5	17-11	Y	21
23	F	E	11-8	16-1	Y	18
24	F	E	12-11	15-11	Y	19
25	M	L	14-3	16-6	N-	31.5
26	F	M	12-10	16-6	Y	22
27	M	M	12-9	16-9	Y	21
28	F	E	13-1	17-8	N-	19
29	M	M	14-3	15-5	Y	21
30	F	L	14-2	15-1	N-	27
31	F	M	13-5	15-7	Y	25
32	F	M	12-1	15-6	Y	22
33	M	L	13-2	15-9	Y	31
34	F	E	14-1	19-1	Y	20
35	F	L	12-2	14-10	Y	27
36	F	E	13-5	15-9	Y	19
37	M	M	13-8	15-4	Y	25

Facial Type: E = euryprosopic, M = mesoprosopic, L = leptoprosopic

Patient Number	(M/F) Sex	Facial Type	Age Start	Age Deband	(Y/N) Extraction	FMA
38	M	L	11-11	17-1	Y	32
39	F	L	12-3	16-6	Y	28
40	M	L	13-8	15-8	Y	28
41	F	E	13-1	16-5	Y	13
42	M	L	12-10	16-5	Y	31
43	M	L	11-11	16-0	Y	36
44	M	M	13-5	15-0	Y	23
45	F	L	15-3	17-5	Y	28
46	F	E	15-0	18-5	Y	10
47	M	L	13-4	15-2	Y	32
48	M	L	13-8	15-5	Y	27
49	M	M	13-11	16-6	Y	21
50	M	M	13-2	15-10	N-	21
51	F	M	12-2	14-0	Y	22
52	M	M	13-2	17-3	Y	23
53	F	L	12-11	15-5	Y	28
54	M	M	14-11	16-8	Y	25
55	F	E	12-9	17-1	Y	20
56	M	L	13-1	17-6	Y	30
57	F	L	13-1	15-8	N-	28
58	M	M	12-11	17-9	Y	26
59	F	E	12-6	14-0	N-	17
60	F	M	13-4	17-8	Y	21
61	F	L	12-4	15-0	Y	27
62	F	L	13-1	15-9	Y	28
63	F	M	13-2	16-2	Y	21
64	M	E	13-11	16-11	Y	19
65	F	E	11-5	14-2	Y	17
66	M	E	13-11	17-5	Y	14
67	F	E	13-3	16-1	Y	20
68	F	E	10-5	15-2	N-	20
69	M	E	13-4	14-4	N-	18
70	M	E	14-2	16-2	Y	20
71	M	E	12-6	15-5	Y	16.5
72	M	E	13-8	15-10	Y	15
73	F	E	12-8	14-6	N-	13
74	F	L	12-11	15-2	Y	29
75	F	E	12-9	15-2	Y	12.5
76	F	L	11-7	14-2	Y	42
77	F	L	13-5	17-2	Y	34
78	F	L	15-6	17-10	Y	34

Facial Type: E = euryprosopic, M = mesoprosopic, L = leptoprosopic

Patient Number	Sex (M/F)	Facial Type	Age Start	Age Deband	Extraction (Y/N)	FMA
79	F	E	14-6	16-5	Y	20
80	M	E	13-4	15-11	Y	18
81	M	M	12-2	14-10	Y	21
82	F	L	13-0	15-5	Y	31
83	M	E	12-1	14-1	N	18
84	F	L	11-10	14-9	Y	32
85	F	E	12-6	16-3	Y	12
86	M	M	14-4	17-10	Y	22
87	F	M	11-7	14-1	Y	27
88	M	M	13-0	15-11	Y	24.5
89	M	L	15-4	16-2	N	35
90	F	M	13-5	16-8	Y	26
91	F	M	12-1	15-8	Y	24
92	M	M	21-8	23-2	Y	26.5
93	M	L	13-9	17-3	Y	32.5
94	M	L	13-6	16-2	Y	37
95	M	M	14-5	16-11	Y	26
96	F	M	13-6	16-4	Y	22
97	M	M	13-2	17-0	Y	25
98	M	L	13-0	15-8	Y	36
99	M	M	13-8	15-3	Y	26
100	M	M	12-10	16-7	Y	22

Facial Type: E = euryprosopic, M = mesoprosopic, L = leptoprosopic

Legend

Technique

B = Begg

T = Tweed

ET = Edgewise-Traditional

ES = Edgewise-Sliding Mechanics

FB = Fourth Stage Begg

MB = Modified Bioprogressive

RW = Round wire, edgewise slots

Headgear

HPHG = High pull headgear with J-hooks

CPHG = Cervical pull headgear

HPFB = High pull facebow

SPHG = Straight pull headgear

APPENDIX II

SUMMARY OF TECHNIQUES AND TREATMENT MECHANICS

Patient Number	Technique	Auxillaries (months)						
		Headgear				Elastics		Other
		HPHG	CPHG	HPFB	SPHG	Class II	III	Bite-plate
1	B					14		
2	B					22		
3	ET		14			4		
4	ET	12				12		3
5	ET	5						
6	ES					5		
7	B					19		
8	MB		8			9		
9	ES					2		
10	ES	6				8		3
11	T	11				13	2	
12	ET	15				2		
13	ES					5		
14	T	24				8		
15	ET	6	9					
16	ES					1		
17	ET	7	2			3		
18	T	20				6		
19	T	9				19		
20	B					23		
21	B					22		
22	B					19		
23	B					10	4	
24	ES					7		4
25	FB					13		
26	B					25		
27	ES					13		
28	MB					3		
29	RW					5		
30	RW					2		
31	T	7				4	6	
32	B					27		
33	ES					10		
34	B					13		
35	FB					5		
36	B					20		

37	FB		6			5		
38	T	10				10		
39	B					12		
40	ES					5		
41	ES					12		
42	T	21				14	6	
43	ES					9		
44	RW					3		
45	ET					7		
46	ES					16		
47	T	9				8		
48	ET	6				6		
49	T	4				3		
50	MB				12	11	12	
51	MB		12		3	2		
52	B					9		
53	B					14		
54	MB			11		2	2	
55	B					22		
56	ES							
57	B					7		
58	B					13		
59	ES					5		4
60	B					28		
61	ES					7		
62	T	24				5	1	
63	B					8	1	
64	ET	5	7			15		3
65	ES	11				6		
66	ET	15	10			15		
67	ES	5	2		9	15		
68	MB	20	16			10		
69	RW					3		
70	ES	12				11		2
71	B					14		
72	ES	12				16		
73	B					11		
74	ES					2		
75	ES		3			7		2
76	MB			2		1	4	
77	B					18		
78	RW					2		
79	B	2				14		
80	B					17		
81	T	15				8		
82	B					22		
83	FB					4		

84	ES			5	
85	ES			16	
86	ET	16		12	
87	T	23		9	
88	ES			2	
89	B			3	
90	B			24	
91	B			11	
92	FB			7	2
93	T			8	
94	T	6		8	2
95	T	12		10	
96	T	8		7	
97	ES			2	
98	ES				
99	ES			4	1
100	B			11	