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CEPHALOMETRIC EVALUATION OF RESPONSE TO ORTHODONTIC TREATMENT OF DEEP OVERBITE WITH CERVICAL PULL FACEBOW HEADGEAR IN EURY-, MESO-, AND LEPTOPROSOPIC INDIVIDUALS

by

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Abstract

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STEPHAN H. PARKER

The correction of deep overbite was studied in 45 patients treated with cervical pull facebow headgear. A control group of 40 untreated deep overbite patients was obtained from the Bolton Study (Cleveland, OH). The control group was matched for age, sex, and facial type.

The groups were divided into three facial types (Euryprosopic, Mesoprosopic, Leptoprosopic) based on anthropomorphic indices. Treatment effects were calculated within and between facial types and the overall effect of cervical pull headgear was assessed, as well as the contribution of facial type.

The following observations were made:

1. Cervical pull facebow headgear reduced overbite significantly in all facial types ($p<.05$).

2. Cervical pull facebow headgear significantly increased maxillary skeletal height (midface) in all facial types ($p<.05$).

3. While upper incisor intrusion accounted for a significant amount of overbite correction in all facial types, the sample showed no lower incisor intrusion. Leptoprosopic individuals exhibited the largest amount of bodily intrusion of the maxillary incisor.

4. Increases in MNSK height and associated molar extrusion was a significant contributor to overbite correction.

5. Significant increases in mandibular plane angle occurred in all facial types (L>E>M). Leptoprosopic (long and narrow) individuals were the most susceptible to downward and backward (clockwise) rotation of the mandible.

6. Although extreme facial types were expected to have opposite or very different responses to the variables studied, it appears that extreme facial types often respond similarly for the changes studied. While facial type may play a role in the treatment of deep overbite, other controlling factors may override the effect of facial type.

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DEDICATION

To my beloved mother, who sacrificed all so that her children could have more.

To my sister Rory. Your friendship and encouragement have been a source of inspiration. I admire you greatly, and I will always be there for you.

To my sister Doreen. Although you are gone, you will be with me daily in my memories. I miss you dearly.

To my mother in-law and father in-law, Ron and Alina. Thank you for treating me like a son.

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LIST OF FIGURES

FIGURE		PAGE
1	Cephalometric tracing with six linear measurements and two angular measurements (M7 and MPA)	34
2	Anterior vertical analysis used in this study. The six linear measurements yield seven variables: MXSK = M1, BUI = M2 - M1, TUI = M3 - M2, TLI = M5 - M4, BLI = M6 - M5, MNSK = M6 - M1, OB = M3 - M4.	38
3	Bar graph depicting the mean for MXSK for each facial type. The treated sample is represented by bars on the right, while the corresponding control sample is represented by bars on the left	76
4	Bar graph depicting the mean for BUI for each facial type. The treated sample is represented by bars on the right, while the corresponding control sample is represented by bars on the left	78
5	Bar graph depicting the mean for TUI for each facial type. The treated sample is represented by bars on the right, while the corresponding control sample is represented by bars on the left	80
6	Bar graph depicting the mean for TLI for each facial type. The treated sample is represented by bars on the right, while the corresponding control sample is represented by bars on the left	82
7	Bar graph depicting the mean for BLI for each facial type. The treated sample is represented by bars on the right, while the corresponding control sample is	84

represented by bars on the left

8 Bar graph depicting the mean for MNSK for each facial type. The treated sample is represented by bars on the right, while the corresponding control sample is represented by bars on the left 86

9 Bar graph depicting the mean for M7 (GO) for each facial type. The treated sample is represented by bars on the right, while the corresponding control sample is represented by bars on the left 88

10 Bar graph depicting the mean for MPA for each facial type. The treated sample is represented by bars on the right, while the corresponding control sample is represented by bars on the left 90

11 Bar graph depicting the mean for OB for each facial type. The treated sample is represented by bars on the right, while the corresponding control sample is represented by bars on the left 92

12 Pie diagrams showing percentage contribution of each variable to overall mid- to lower anterior facial height change for all facial types. Stars represent negative contributions to overbite correction 94

13 Pie diagrams showing percentage contribution of each variable to overall mid- to lower anterior facial height change for euryprosopic facial types. Stars represent negative contributions to overbite correction 96

14 Pie diagrams showing percentage contribution of each variable to 98

overall mid- to lower anterior facial height change for mesoprosopic facial types. Stars represent negative contributions to overbite correction

15 Pie diagram showing percentage contribution of each variable to overall mid- to lower anterior facial height change for leptoprosopic facial types. Stars represent negative contributions to overbite correction 100

LIST OF TABLES

TABLE		PAGE
I	Description of Sample	30
II	Descriptive Statistics Assessment of Measurement Error	43
III	Descriptive Statistics Assessment of Tracing Error	44
IV	Relliability Coefficients Assessing Measurement Error	45
V	Reliability Coefficients Assessing Tracing Error	46
VI	Descriptive Statistics Means and Standard Error of the Means Comparing Control and Treated Groups	49
VII	P Values for Treatment and Facial Form	51
VIII	One-Way ANOVA for Treated and Facial Form	52
IX	P Values for Two Way ANOVA	54
X	Summary of Sign Conversions	74
XI	Mean Change Between Treated and Control Groups ($X_{treated} - X_{control}$) Representing the Effect of Treatment Controlling for Growth (in mm)	75

TABLE OF CONTENTS

	PAGE
ABSTRACT	ii
ACKNOWLEDGMENTS	iv
DEDICATION	vii
LIST OF FIGURES	viii
LIST OF TABLES	ix
INTRODUCTION	1
REVIEW OF LITERATURE	3
STATEMENT OF THESIS	27
MATERIALS AND METHODS	29
RESULTS	41
DISCUSSION	55
SUMMARY AND CONCLUSIONS	102
LITERATURE CITED	105

INTRODUCTION

Ever since Kloehn first introduced the cervical pull facebow headgear in 1947, clinicians have debated its usefulness as a tool for the correction of Class II malocclusion. Many studies have reported both favorable and unfavorable effects on growth and development that accompany the use of cervical headgear (Kloehn, 1947; Graber, 1954; King, 1957; Ricketts, 1960; Poulton, 1959; Merrifield and Cross, 1970).

The correction of deep overbite remains "one of the most difficult problems in orthodontia" (Grieve, 1928). The etiology of a deep bite and how it should best be treated remains controversial (Ricketts, 1960; Merrifield, 1970; Burstone, 1977; Schudy, 1968). Four factors contribute to overbite correction: 1) molar extrusion, 2) incisor intrusion, 3) growth of the maxilla, and 4) growth of the mandible (Simons and Joondeph, 1973; Engel, 1980). Changes in the position of the teeth, maxilla, and mandible have been studied by various cephalometric analyses (Thompson, 1979; Otto, 1980) which account for changes in growth by adjustment with a numerical factor or by regional superimposition and comparison with untreated control

samples (Creekmore, 1967; Weislander, 1974). Although many different methods have been proposed for the correction of deep overbite, the relative contributions of tooth movement, skeletal change, and growth still remain unclear.

Until recently, true vertical changes in incisor position were impossible to assess, since labial tipping components were not separated from genuine intrusion. Kishiyama (1987) devised a method of analyzing true vertical changes that occur with treatment during tooth movement and skeletal growth.

Overbite correction must necessarily be the result of either tooth movement alone or tooth movement in combination with facial growth. This study utilizes the vertical analysis developed by Kishiyama (1987) to assess changes in overbite that accompany non-extraction treatment with cervical pull headgear. The study will report on the relative contributions of tipping, intrusive, and extrusive tooth movements, and vertical facial growth in the correction of deep overbite malocclusion.

LITERATURE REVIEW

Since its introduction in 1947, Kloehn facebow headgear has become widely used in the correction of Class II malocclusion (Kloehn, 1947; Ricketts, 1960; Contasti, 1982; Cetlin, 1983; Cangialosi et al., 1988). Many studies have examined the effects of the cervical facebow on growth and development (Graber, 1954; Poulton, 1967; Maguire, 1972; Weislander, 1974; Melsen, 1988). Results of previous studies on treatment with extraoral traction have shown variable effects from simple tooth movement to changes in alveolar prognathism and alteration of the entire maxillary complex. Two studies have found effects on distant structures such as the sphenoid bone (Weislander, 1974; Chaconas, 1976). Benefits of cervical facebow therapy in the correction of antero-posterior Class II dental discrepancies, such as reduction of facial convexity, reduction of flaring of maxillary incisors and correction of class II molar relationship, have been well documented (Kloehn, 1947; King, 1957; Cangialosi, 1988).

Ricketts (1960) and others have also emphasized the use of cervical headgear as an orthopedic device to change the growth of the maxilla in patients with skeletal dysplasias.

The use of cervical facebow headgear has been criticized by many who feel that the "reactive forces" (Fischer, 1980) of the cervical facebow adversely affect treatment. Schudy (1965), Poulton (1967), and Merrifield and Cross (1970) have reported cases in which they believed adverse effects occurred with cervical headgear. Merrifield and Cross (1970) have referred to these effects as the "cervical facebow reaction." Also known as the "Kloehn reaction", this includes "... relapse of Class II cases, lack of facial improvement, difficulty of reducing ANB, upper second molar problems..., torque of upper incisors, a 'toothy' smile..., and mandibular rotation."

Different studies have found varying treatment effects with cervical facebow headgear. King (1957) found that fifty cases treated with cervical facebow headgear all exhibited a downward growth of the mandible in excess of forward growth. However, changes in mandibular plane angle were insignificant.

Kloehn (1947) reported no significant elongation of molar teeth or bite opening due to mandibular rotation. Newcomb (1958) observed that the mandibular plane would close subsequently if opened during treatment. It was Newcomb's belief

that depending on the timing of treatment, growth could play a significant role in changes that were achieved during and after treatment.

Ricketts (1960) found a direct relationship between molar extrusion and a decrease in downward and foward mandibular growth and cautioned against the possibility of openbite in patients where bite opening mechanics are used with limited mandibular growth potential.

Schudy (1965) and Poulton (1967) also felt that cervical headgear extruded molars and that if the mandibular plane opened during treatment, only growth of the condyles could restore the mandible back to its original inclination. Schudy (1965) found that vertical elongation of the molars with facebow headgear resulted in increased vertical facial height and a steeper mandibular plane angle. These effects are similar to those seen with a decrease in condylar growth.

Silverstein (1954) felt that the clockwise rotation of the mandible and the lack of improvement of the facial angle was due to cervical headgear therapy. He reported that mandibular growth was inhibited.

The main objection to the use of cervical

headgear is that it will usually cause extrusion of the maxillary molars. This is often considered undesirable except in the treatment of patients with short lower facial height (Contasti, 1982). Tweed (1954) wanted to avoid extrusion of molars and based his mechanics on preventing molar extrusion (Barton, 1972). Merrifield and Cross (1970) studied cases treated with cervical pull facebow headgear. In their study they found considerable molar extrusion resulting in clockwise mandibular rotation, and subsequent increase in mandibular plane angle. The lower part of the face did not come forward as would be desirable in a Class II case. In one case discussed, the mandibular plane angle increased 3 degrees. An increase in mandibular plane angle and the downward and backward movement of the mandible was "common following the use of the cervical face-bow..." (Merrifield and Cross, 1970). It was their belief that "extrusion of the upper molar is equal to downward growth of the maxilla." They felt that "downward growth of the maxilla is equivalent to forward growth of the maxilla..." and that these effects must not be produced with orthodontic forces. Merrifield and Cross concluded that there was no place for the "actions" of cervical pull facebow

headgear.

Moore (1959) studied cases treated with cervical pull facebow headgear and found that 54% of the treated group grew down or backward. In the untreated groups, only 10% of the group grew down and backward. This can be assessed by analyzing the changes in mandibular skeletal length (MNSK) (Kishiyama, 1987) and mandibular plane angle changes (MPA), since downward and backward growth is synonymous with extrusion of maxillary molars (Merrifield and Cross, 1970), an increase in MNSK indicates maxillary molar extrusion (Kishiyama, 1987) and vertical facial growth. Changes in MPA must be used to distinguish between molar extrusion and vertical growth.

Graber (1954) reported preliminary findings on 65 (of a total of 150) Class II Division I cases using cervical headgear, a heavy gauge maxillary arch wire, and acrylic bite plates in those cases where the overbite was deep. He found that it is possible to change the maxillo-mandibular base relationship and eliminate Class II tooth intercuspation with cervical pull facebow headgear. The mandibular incisors were not significantly tipped, except in cases where bite plates were used. The bite plate

was used to provide clearance for retracting maxillary incisors. The effect of the bite plate on mandibular growth and molar extrusion could not be determined. In severe cases, the maxillary incisors were inclined lingually to reduce overjet.

Poulton (1959) examined the changes in Class II malocclusion with and without occipital J-hook headgear. He found that occipital headgear was the most effective appliance for moving teeth posteriorly. Incisor position was improved and molar relationship corrected. He emphasized the need to use an untreated control group comparable to the treatment group. He also felt that everyday wear was the most important factor for successful treatment. His group only studied effects over a one year period, which may be too short a time period. Poulton (1967) felt that it was not possible to influence mandibular growth with headgear and that "there is no convincing evidence that this (mandibular growth) can be changed through appliance therapy" (Cohen, 1966; Poulton, 1967). It was his belief that treatment efforts were directed toward retraction of the maxillary teeth in order to correct the problem.

Maguire (1972) studied the contribution of

extraoral force to the maxillary molars in reduction of Class II molar relationship and overbite correction. He used one group of 44 patients treated with the Begg appliance and one group of 33 patients treated with an Edgewise appliance. The Edgewise group utilized high pull facebow headgear, whereas the extraoral force utilized in the Begg group varied from low-pull (cervical) to high pull facebow headgear. Changes in the position of the maxillary first molar were studied by superimposing pre- and post-treatment tracings along the sella-nasion line with sella registered and along the palatal plane with the anterior nasal spine outline registered. He found a significant correlation in both groups between distal tipping and extrusion of maxillary molars and extrusion of mandibular molars with overbite correction. Although the palatal plane angulation increased, it was not significantly correlated to overbite correction. There was no mention of how overbite correction was measured and no control group was used for comparison.

Barton (1972) compared the use of anterior highpull headgear (J-hook) to cervical traction in 20 cases. His cases were all treated with extraction. He compared pre- and post-treatment cephalograms to

determine which form of therapy allowed the mandible to assume the most favorable position while retracting teeth. He found that cervical traction to the maxillary molars tends to extrude the maxillary molars more and causes the mandible to rotate further clockwise than with highpull canine headgear. He also showed that the highpull headgear allows the chin to come further foward than with cervical traction. He felt that the faces were not as desirable with cervical headgear. Unlike other studies, Barton extracted four first premolars in all cases. It is possible that the cervical headgear was too effective in reduction of maxillary protrusion with extractions.

Weislander (1974) studied the effect of cervical traction on craniofacial development. His treatment group consisted of 28 Class II division I malocclusions with an average of 12-14 hours of headgear wear per day, heavy forces (10-15oz), and a treatment time of 2.8 years. Weislander wanted to investigate whether the treatment effect was more than just dento-alveolar. Using the method of superimposing the anterior cranial base and frontal sinus, he found that there was a clockwise rotation of the pterygoid plates and sphenoid bones in the

treatment group relative to a control group. In addition, the treated group had an ANB reduction of 3 degrees, slight tipping of the palatal plane, inferior movement of Nasion, maxillary molar distalization of 5mm and a slight clockwise rotation of the mandible.

Badell (1976) studied the effect of combined highpull traction and cervical traction to the maxilla utilizing heavy forces (2.5-3lbs/side). He found that he could deliver an orthopedic force by using high forces and splinting all the teeth together. By utilizing combined forces, extrusion of the molars did not occur. In fact, the maxillary molar was intruded slightly. He feels that this is a viable treatment option when significant extrusion is not desired. Unlike Weislander (1974), who demonstrated a minimal physiological recovery of the maxillary first molar with cervical headgear therapy, Badell found a strong tendency for recovery. It may be significant that Badell's patients only wore the headgear for an average of 122 days. The effect of such high forces has also not been considered.

Melsen (1978) studied the effect of cervical traction in relationship to tilt of the outer bow. He utilized implants in 20 children in which the

outer bow was tipped 20 degrees up and half tipped 20 degrees down. Although there was greater tipping of molars in the cases were the bow was tilted down, Melsen found that the same degree of extrusion had occurred in both groups. This would imply that other factors, such a occlusal forces and occlusal contact relationships, may play a role in determining the final results.

Melsen (1978) also found that while the growth direction of the maxilla had been changed dramatically, discontinued use of the headgear was followed by increased "catch up" growth of the maxilla and foward anterior rotation of the mandible, possibly indicating that the influence of the headgear was only temporary and the stability was dependant on dentoalveolar remodeling. Of significance is the fact that the cases were only treated for 8 months, perhaps too short a time period to achieve stable results.

Another interesting finding was that individual cephalometric results did not give any indication as to which subjects would be expected to show posterior rotation of the mandible after cervical traction. In the two patients who showed posterior rotation after treatment, "neither inclination nor shape of the

mandible" gave any clues to prediction of results. This is in contrast to the belief that mandibular plane angle or mandibular growth pattern is an indicator of type of anchorage. Although these cases were followed 6-7 years post-retention, they only received an average of 8 months of cervical traction therapy. It is possible that longer treatment time is necessary in order for long term stability of results, especially in light of the pronounced post-treatment anterior growth pattern shown in all but two subjects. Also, the use of implants appears to be an excellent method of studying changes; however, their use is not accepted in the United States.

Experimental studies have also been done on non-human models to assess the effects of headgear therapy. Chaconas (1976), in an attempt to determine the nature of forces transmitted by cervical and highpull orthopedic headgear to the craniofacial skeleton, used a three dimensional human skull replica made out of various birefringent materials which simulate bone, teeth, and periodontal ligament. Chaconas found that cervical headgear was more effective than high-pull orthopedic traction in transmitting forces to both distant craniofacial structures and to the teeth. Both types of headgear

affected the position of the maxillary first molar. However, there were no forces of occlusion or muscular forces to interact with and/or affect the headgear therapy.

To further investigate the impact of headgear, Dermaut (1986) studied the effect of facebow headgear on dry macerated skulls using laser speckle interferometry. He observed various types of molar movement and determined the center of resistance to be slightly occlusal to the first molar trifurcation. Again, there were no forces of occlusion present. However, this confirmed the work of previous authors (Worms, 1973).

Brandt (1979) looked at the effect of Kloehn headgear in the adult non-human primate and found that even in adults, facial sutures respond to extra-oral forces, although the response is slower in onset. The stage of sutural growth activity has little effect on the remodeling of sutural articulations, as long as synostosis had not occurred. Thus, while the growing child appears to be the ideal candidate for facial alteration, the young adult may respond to such treatment as well.

Though many investigators have studied cervical headgear reaction, the exact clinical relationship of

cervical facebow traction to molar extrusion and mandibular rotation remains ill-defined. While molar extrusion does occur, its clinical effect and significance remain unclear. Though some authors say that cervical headgear should not be used in cases of higher than average mandibular plane angle (MPA), MPA may not be an appropriate gauge for determining the headgear's usefulness. Many principles remain hypothetical and await investigation (Bowden, 1978).

Review of Deep Overbite

The difficulty of correcting a deep bite has been recognized since early orthodontics. Grieve (1928) described this as the most difficult problem in orthodontic treatment.

There is certainly much controversy as to the definition and cause of deep overbite, both skeletal and dental. Many clinicians have studied the correction of deepbite with cephalometrics. In a study of deep overbite by Kishiyama, (1987), excessive deep overbite was defined cephalometrically by the extension of the lower incisor edge beyond the cingulum of the maxillary incisors.

Bonwell (1925) felt that the amount of anterior overbite was determined by the depth of posterior

cusps. Steadman (1949) examined the relationship of the upper anterior teeth to the lower anterior teeth as present on plaster models of a group of acceptable individuals and reported that overbite was directly proportional to interincisal angle. Buckland (1958) found the angle between the lingual surfaces of the upper and lower incisors to correlate best with stability of deepbite correction, rather that axial inclination.

Jackson (1938) believed deepbite was a result of vertical eruption of maxillary and mandibular incisors. Prakash and Margolis (1952) showed a negative correlation between eruption of lower molars and overbite. Others (Strang, 1934; Mershon, 1937; Steadman, 1952) believe that a combination of infraeruption of posterior teeth and supereruption of anterior teeth produce deep overbite. Barton (1972) believed the extent of posterior and anterior vertical tooth eruption were ultimately determined by the patient's muscular forces.

Mershon (1937) divided deepbites into two categories: 1) true closed bites which were associated with infraocclusion of molars and strong musculature, and 2) deepbites due to supraocclusion of incisors, which he feels can be treated with

intrusion.

Grieve (1928) attributed deep bites to antero-posterior problems, including protrusion of maxillary teeth, a deficient mandible, or both. Baume (1950) described the importance of mandibular growth in determining overbite. He observed that deficient foward growth of the mandible during tooth eruption was associated with deepbite.

Strang (1934) and Hemley (1938) believed that the deep overbite relationship was related to problems in posterior and anterior vertical tooth eruption and implicated muscular forces in the development of deep overbite.

Carlyle (1977) studied overbite relationships and found that deep overbite is associated with reduced dentoalveolar vertical molar height, retrusive lower incisors, and a small posteriorly positioned mandible relative to the maxilla and cranial base.

There is much controversy over the best way to treat a deep bite. Schudy (1968) felt that eruption of premolars and molars to rotate the mandible open was the treatment of choice in most cases. Ricketts (1979) and Burstone (1977) advocate intrusion of incisors. Engel (1980) reviewed the treatment of

deep overbite cases and found that a majority of cases are treated with a combination of incisor intrusion, incisor proclination, and mandibular rotation. Also, since growth tends to increase vertical distance between the maxilla and mandible, it is probably useful to treat these deepbite cases during a period of growth. However, all deep bite cases presented with the problem of significant relapse potential.

Theory and Principles of Cervical Headgear Therapy

The efficient use of cervical headgear requires a thorough understanding of basic biomechanics in order to properly control the direction and magnitude of the forces produced and achieve a desirable clinical result (Contasti, 1982). When a force is directed against a body, the body moves by either translation (bodily movement), rotation (tipping), or a combination of both. There are four essentials to consider when using cervical facebow headgear: 1) the center of resistance and rotation, 2) the force employed, 3) the direction of movement, and 4) the duration of wear (Worms, et al., 1973).

Cervical pull facebow headgear is applied to the maxillary first molars. The inner bow fits into

tubes attached either occlusally or gingivally, depending on the clinicians desires, and lies parallel to the occlusal plane. The outer bow is adjusted, according to the type of movement desired. The center of resistance (CR), located approximately at the trifurcation of the first molar root, is the point through which a single force will cause pure translation of the molar. When the line of force (LF) is applied through the CR, no molar tipping will occur. If the LF is applied superiorly, the center of rotation will move coronally and a counter clockwise moment will occur. An inferiorly positioned LF will displace the center of rotation apically and result in a clockwise molar rotation . Altering the direction of the LF determines the vertical component, which is so critical in orthodontic treatment (Contasti, 1982).

The movement of a molar depends upon the perpendicular distance between the force vector and the center of resistance. The amount of rotation or translation depends on the location of the instantaneous center of rotation. If the center of rotation is near the center of resistance, the molar will rotate. As the center of rotation approaches infinity, translation will occur. As the line of

force moves away from the center of resistance, the center of rotation approaches CR. As LF approaches CR, the center of rotation moves toward infinity and translation occurs. Worms (1973) demonstrated that the direction of the headgear force system could be altered clinically to produce either extrusion, intrusion, mesial, or distal movement, and varying combinations of these effects. This required a well planned adjustment of the headgear.

The greater the distance from the CR to the line of force applied, the greater the moment and subsequent rotation. The LFO is a line from the strap force application point through the maxillary molar center of resistance. When the outer bow lies along the LFO, pure bodily translation in a posterior and extrusive direction will occur with no rotation. If the outer bow is placed above the LFO, a counterclockwise moment is produced. If the outer bow is placed below the LFO, there will be a clockwise moment produced (rotation). In most applications, cervical pull facebow headgear will have an extrusive component of force acting on the molars. It is only when the outer bow lies below the neck strap that the resultant force will be intrusive instead of extrusive. Additionally, this will be

accompanied by distal displacement and a large counterclockwise rotation.

Facial Form and Overbite

Orthodontists have asserted that the correction of a malocclusion is dependant on the patient's facial form (Ricketts, 1960; Schudy, 1968; Creekmore, 1967). The relationship between overbite and facial form has been examined extensively. It is widely believed that patients with different facial types will respond differently to orthodontic treatment and require different forms of management in order to treat the malocclusion.

Wylie (1946) examined the relationship between total facial height and vertical overbite. He found that as the overbite depth increased, the facial height became smaller. Bjork (1947) examined the relationship between mandibular plane-occlusal plane angle and found that individuals with larger overbites had a smaller occlusal-mandibular plane angle.

Schudy (1966, 1963) studied the relationship between vertical overbite and the occlusal mandibular plane. He found that the amount of overbite was related to the facial pattern. Schudy's sample

consisted of patients with an overbite range of -4mm (openbite) to +10mm. Ludwig (1967) examined a sample with only deep overbites of 5mm or more and found that "there was no significant correlation between pretreatment overbite and the facial pattern of the individual." This contradicted Schudy's findings.

Creekmore (1967) examined the effects of orthodontic treatment on vertical growth of the face. He studied vertical growth changes in treated and untreated controls and found that orthodontic treatment resulted in considerable molar extrusion and affected the vertical dimension and, consequently , facial form. Price and Creekmore (1967) found that high angle cases without orthodontic treatment are more susceptible to vertical increase than average facial types, and that the converse was true for low angle cases. Creekmore believed that different facial types should be treated differently (Kishiyama, 1987). Schudy (1968) supported this belief and felt that an individual's facial type was more important in determining an individual's response to treatment than the amount of overbite present.

Many authors (Burstone, 1977; Ricketts, 1964; Bench, 1978) have examined intrusion of lower

incisors as a means of overbite correction. Ricketts and Bench both believed that symphyseal morphology directly affects the ease of incisor intrusion, and that brachycephallic individuals have wider symphyses which may allow for easier intrusion of mandibular incisors.

The question of incisor intrusion verses molar extrusion has been debated previously. Ricketts (1960) and Burstone (1977) felt that for short faces, posterior eruption is indicated, whereas for long faces posterior extrusion should be avoided. However, in cases where there is an average facial pattern, the question of molar extrusion verses incisor intrusion is much less clear. While some authors advocate some form of incisor intrusion in these cases (Burstone, 1977; DiGiulio, 1983; Engel, 1980), others advocate extrusion of posterior teeth (Schudy, 1963; Creekmore, 1967). In reality, most clinicians probably achieve a combination of incisor intrusion and molar extrusion.

Growth, Treatment, and Changes in Overbite

Many authors have attempted to establish relationships between growth and changes in overbite. Bjork (1953) found that although individual variation

was high, there was a general decrease in the overbite with age, and that deep overbites tended to open more than normal overbites. Schudy (1968) felt that since downward maxillary growth accounted for 70% of the total vertical growth of the face, this was the most important factor in establishing facial height and affecting overbite. Bjork and Skeiller (1972) implicated growth rotations of the mandible in affecting overbite increase or decrease.

Review of various studies (Baume, 1950; Bjork, 1953; Moorees, 1959; Herness, 1973; Moyers, 1976) shows a considerable lack of agreement regarding increase or decrease of overbite with age.

Separating the effects of treatment from normal growth is necessary in order to understand the changes that take place over time. Review of the literature shows that investigators have used many different methods to evaluate growth and treatment changes. Some investigators employ the use of untreated control subjects (Creekmore, 1967; Weislander, 1974). Some investigators have devised cephalometric measurements that represent growth areas which can be factored out, leaving the final value as treatment change (Thompson, 1979; Otto, 1980). And some studies have failed to address the

role of growth in overbite correction (Barton, 1972; Carlyle, 1977).

Separating orthodontic treatment effects from changes which would have occurred with growth alone is extremely important, especially since studies have shown that deep overbites tend to improve through the passage of time even without treatment (Bjork, 1953; Fleming, 1961).

Measurement of Vertical Tooth Movement

Several different methods of defining incisor movement have been used in the literature. In his attempt to classify the vertical incisor movement during therapy, Kishiyama (1987) found it necessary to differentiate between true intrusion (McDowell, 1970) and "tipping depression" (Thurow, 1962), or what Burstone (1977) called "pseudo-intrusion" defined as "labial tipping around its centroid."

Liu and Herschleb (1981) defined tooth movement by its vertical and horizontal components and its axial inclination. They defined pure intrusion as a pure vertical displacement of the center of resistance where the axial inclination of the tooth remains the same.

Different methods of measuring the amount of

intrusion have been employed. Otto (1980) used templates to draw the incisor and give a consistent orientation of the apices. He measured intrusion at the root apices as an assessment of bodily intrusion. Measurements from the incisal tip can be erroneous since position of the incisal tip is most affected by tipping of the tooth. Measurements from the root apices are less affected by tipping. However, the apex is often subject to root resorption, which would affect the measurement.

Burstone (1977) stated that intrusion should be measured from the centroid of the tooth, due to the inherent limitations of other methods. Liu and Herschleb (1981) defined the center of resistance of the lower incisor at 40% of the root length. Root length was defined as the distance from the root apex to the alveolar bone crest. This method was used by Kishiyama (1987).

STATEMENT OF THESIS

The purpose of this study was to evaluate the effect of cervical pull facebow headgear on the orthodontic correction of deepbite malocclusion. A random sample of 45 patients treated with cervical pull facebow headgear was obtained. The group was stratified according to facial type, age and sex. Pre-treatment and deband cephalometric radiographs were traced and compared in order to evaluate changes that occurred with orthodontic treatment.

A similar group of untreated controls was obtained from the Bolton Study (Cleveland, Ohio) so that the effect of normal growth and development could be quantitatively assessed. The control group was matched with the treated group according to facial type, age, and sex. In this way the effect of change that occurs with normal growth and development can be separated from the change that occurs with treatment.

In order to quantify the exact nature of tooth movement and skeletal change, a vertical analysis, developed by Kishiyama (1987), was modified and employed. Since the facial type of an individual is thought to influence both growth and treatment effects, the groups were stratified according to

facial type and statistical analysis done to determine the significance of facial type on the relative contributions of growth and treatment to the orthodontic correction of deep overbite.

MATERIALS AND METHODS

Sample

Forty-five patients with 100% overbite who were treated without extraction of teeth, with cervical pull headgear (Kloehn-type), and had adequate pre-treatment (T1) and deband (T2) cephalograms were obtained from a private orthodontic office in Akron, Ohio. Forty untreated control patient records were obtained from the Bolton Study (Cleveland, Ohio). The groups were matched according to facial type, age, sex, and overbite (Table I). An overbite was considered excessive if the lower incisal edge was beyond the cingulum of the maxillary incisor. This was determined cephalometrically.

The treated sample was divided according to facial type by the use of anthropometric values: euryprosopic (wide and short), mesoprosopic (intermediate), and leptoprosopic (narrow and long).

Determination of facial form required the availability of both lateral and frontal cephalograms. The facial index was calculated as the ratio of the length of Nasion to Menton divided by the Bizygomatic width. Measurements were determined with a millimetric ruler accurate to the nearest 0.1 mm. Facial form was then determined from facial

TABLE I

Description of Sample

Treated group

Facial Type	N	Male	Female
Euryprosopic	18	11	7
Mesoprosopic	18	9	9
Leptoprosopic	9	8	1

Control Group

Facial Type	N	Male	Female
Euryprosopic	9	5	4
Mesoprosopic	21	11	10
Leptoprosopic	10	8	2

index (FI) defined by Hrdlicka (1947) as follows:

Hypereuryprosopic.....	X - 79.9
Euryprosopic.....	80 - 84.9
Mesoprosopic.....	85 - 89.9
Leptoprosopic.....	90 - X

where

FI = {(Na - Me)/(Bizygomatic width)}* 100%

(Wilder, 1920).

In cases where frontal radiographs were not available, clinical slides were used to measure the soft tissue facial index. The slides were projected onto a Diastar 200 viewer (Osram Corporation, Austria) and soft tissue landmarks were identified. Soft tissue Zygion is the most lateral point of each zygomatic arch. It is identical to the Zygion of the malar bones. Soft tissue Menton is the lowest median landmark on the lower border of the mandible. It is identical to the bony Menton. Soft tissue Nasion is the point of both the nasal root and the nasofrontal suture. This point is always above the line that connects the inner canthi (Farkas, 1981). Kishiyama (1987) found that using clinical photographs was a valid method for measuring the soft tissue facial index.

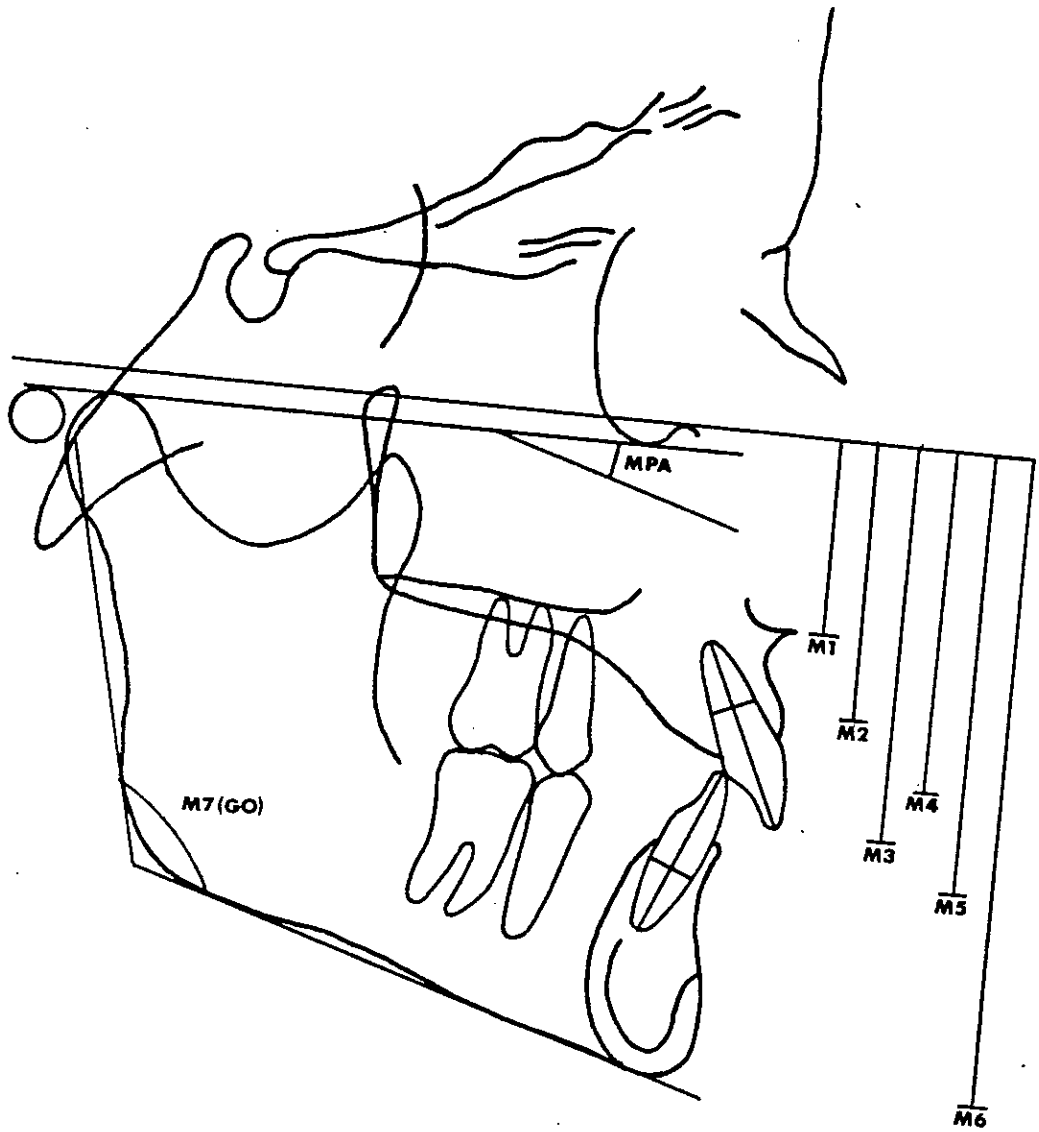
Technical Details

All radiographs were traced on .003" matte

acetate with a 0.5 mm H lead mechanical pencil. In all tracings bilateral anatomical landmarks were bisected and the midpoint taken for cephalometric measurement in order to reduce all landmarks to their mid-sagittal value and reduce error. Landmarks were traced according to Kishiyama (1987) to allow identification of registration points (Fig. 1). Descriptive and statistical analyses were used to compare pre-and post-treatment values.

To evaluate anatomical changes from time one (T1) to time two (T2), a method of superimposition was employed utilizing the sphenoethmoidal junction and anterior cranial base (Elmejian, 1959). This is in contrast to Kishiyama's use of Pt-Orbitale+3 line as a method of superimpostion. After all landmarks were traced, a fiducial horizontal reference line was constructed from Pt point to a point 3mm above Orbitale. This line represents the path of the maxillary nerve and approximately parallels the palate duting development (Enlow, 1982; Moss, 1967). This fiducial line was then transferred to the T2 (or C2) tracing by superimposing the T2 (or C2) tracing on the T1 (or T2) tracing using the sphenoethmoidal junction and the anterior cranial base as a stable reference marker (Elmejian, 1959). The center of

Figure 1. Cephalometric tracing with six linear measurements and two angular measurements (M7 and MPA).


MPA
M1
M2
M3
M4
M5
M6
M7(GO)

resistance of the upper and lower incisors was estimated to be 40% of the distance from the alveolar crest to the root apex (Liu and Herschleb, 1981). This measurement was made with a millimetric ruler accurate to the nearest 0.1mm and was marked on the long axis of each incisor at T1 (or C1). This distance was then transferred to the corresponding incisor at T2 (or C2). Intra-investigator error was assessed by retracing 20 randomly chosen radiographs. Statistical analysis was then performed to determine tracing error.

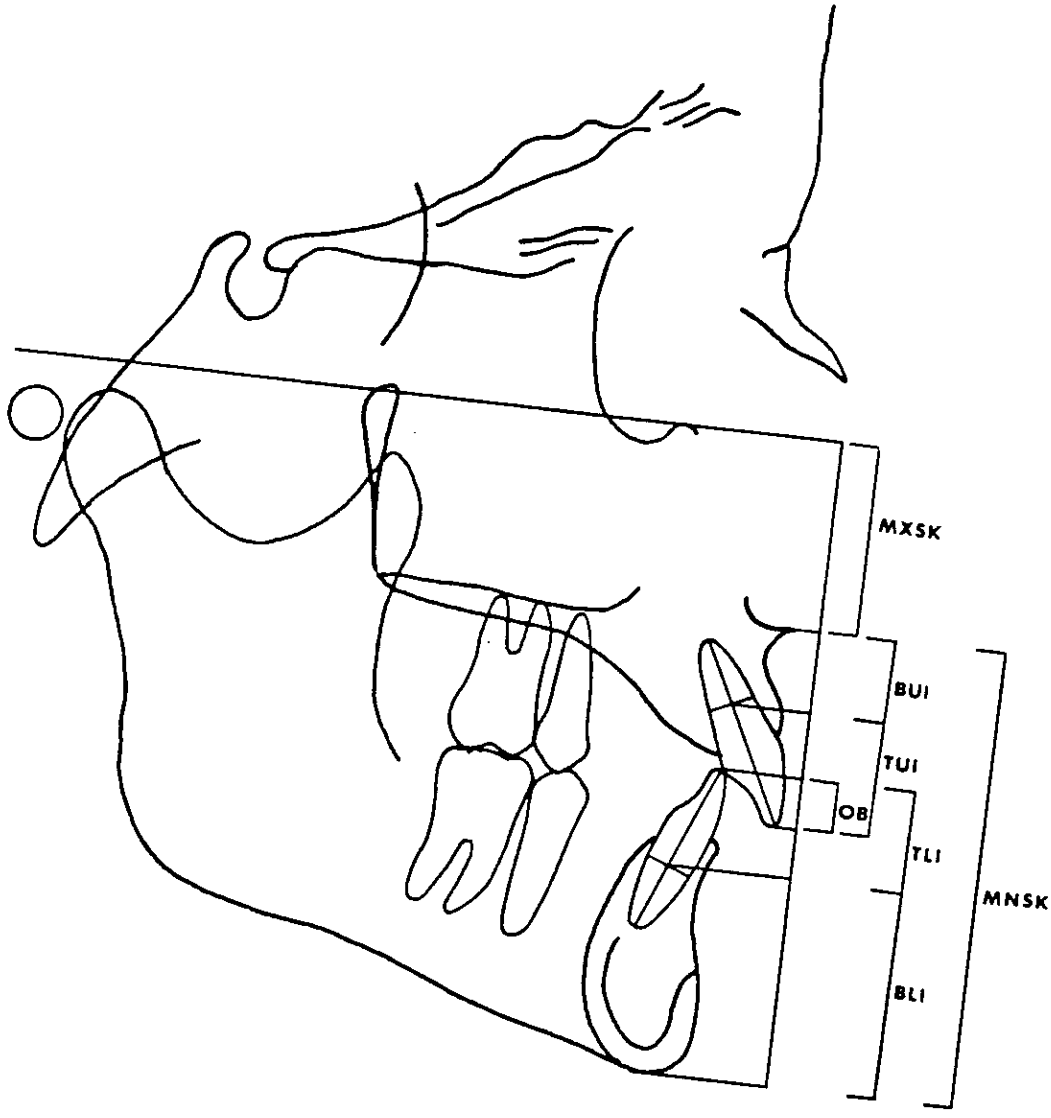
Six linear distances were measured. From these measurements 7 variables forming the basis of the analysis were calculated (Kishiyama, 1987) (Figs. 1 and 2). All linear distances were measured from a perpendicular horizontal reference line, Pterygoid point to point 3 mm above Orbitale (T1 and C1), and constructed Pt-Or+3 line (T2 and C2). The constructed plane was transferred from the initial tracing by superimposition on the sphenoethmoidal junction and the anterior cranial base best fit (Elmejian, 1959). This method of superimposition is considered very accurate since the area employed is considered extremely stable and unchanged in shape and size over time.

The following abbreviations were used for the measured distances in the anterior vertical analysis (Figs. 1 and 2).

Measurement 1 (M1) = Distance from the reference line to ANS.
Measurement 2 (M2) = Distance from the reference line to the CR of the maxillary incisor.
Measurement 3 (M3) = Distance from the reference line to the incisal edge of the mandibular 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 change in length from the reference line to ANS, which is measurement 1 (M1). Bodily movement of the maxillary incisor (BUI) evaluates the amount of extrusion or intrusion and is calculated by subtracting M1 from M2. Vertical changes of the maxillary incisor due to tipping (TUI) is assessed by subtracting M2 from M3. Similarly, tipping (TLI) and bodily (BLI) movement of the lower incisor is determined by subtracting M4 from M5 and M5 from M6, respectively. Mandibular skeletal change (MNSK) is calculated by M6 - M1 and overbite (OB) is equal to M3 - M4. MNSK is a measure of mandibular skeletal

Figure 2. Anterior vertical analysis used in this study. The six linear measurements yield seven variables: MXSK = M1, BUI = M2 - M1, TUI = M3 - M2, TLI = M5 - M4, BLI = M6 - M5, MNSK = M6 - M1, OB = M3 - M4.


MXSK
BUI
TUI
OB
TLI
MNSK
BLI

displacement and molar extrusion accompanies increased MNSK change (Kishiyama, 1987).

Richardson (1969) and Moss and Salentijn (1971) considered the shape of the mandible to be more important than the size in the deep overbite patient. Therefore, gonial angle was also measured. In addition, mandibular plane angle was also measured (Fig. 1).

Statistical Methods

Data analysis was performed utilizing the Statistical Package for the Social Sciences (SPSS) at the A.R. Jennings Computing Center at Case Western Reserve University (Cleveland, Ohio).

The purpose of the study was to evaluate the effect of cervical pull headgear on overbite correction in various facial types. Initially, the various facial type groupings were pooled, forming a treated and control group. Delta values for the changes being analyzed were then determined by subtracting the difference between T1 (C1) and T2 (C2). T-tests were used to compare differences between the means of the treated and control groups. Student t-tests were also used to compare differences between the treated and control groups within each

facial type. A Two-way Analysis of Variance (ANOVA) was performed to assess difference in treatment result among the different facial types, to examine the differences in growth among facial types, and to study the effect of gender on treatment response. A one-way ANOVA was run to test differences among facial types and the variables studied.

Measurement of Experimental Error

Repeat measurements of M1 - M7 and MPA were done on ten random tracings to determine degree of investigator measurement error. Values for changes in MXSK, BUI, TUI, BLI, TLI, MNSK, OB, MPA, and GO were calculated from the second set of measurements and compared to values calculated from the original measurements. Paired t-tests and a coefficient of linear correlation, r, was then calculated for each of these values. The square of the coefficient, r^2, was then calculated as a measure of true variance.

To determine degree of investigator tracing error, these same ten patients were then retraced. Measurements and calculations were made from the second set of tracings and compared to these from the first set of tracings. Paired t-tests and r values were also calculated.

RESULTS

I. PATIENTS

The treated group consisted of 28 males (62%) and 17 females (38%) with an average age of 11 years 3 months at the beginning of treatment and 14 years 4 months at the end of treatment. Eighteen (40%) patients were euryprosopic, 18 (40%) patients were mesoprosopic, and 9 (20%) were leptoprosopic. The control group was similar to the treatment group in all of these parameters (including an average age at C1 of 11 years 2 months and an average age at C2 of 14 years 4 months).

II. ERROR ANALYSIS

Repeat measurements of M1-M7 and MPA were done on ten random tracings. Values for MXSK, BUI, TUI, OB, TLI, BLI, MNSK, GO, and MPA were then calculated and compared with the original measurements. T-tests were performed and no significant differences were found between the second set of measurements and the original set. This would indicate that there was no significant error due to measurement errors.

To determine the degree of intra-investigator tracing error, ten patients were retraced. The values from the second set of tracings for the

variables studied were then compared to the first set of calculated values. T-tests were computed and no significant difference was found for MXSK, BUI, BLI, TLI, OB, MNSK, GO, and MPA. However, a small but significant ($p<.05$) difference for TUI was found between the second tracing and original tracing. This would indicate that any differences in the value for change in TUI may not be able to be explained by normal differences in the sample population. The values for the t-tests are in Tables II and III.

Reliability coefficients assessing measurement and tracing error were also computed (Tables IV and V). The higher the r value, the more accurately the point was located upon remeasurement or retracing. An r value of 1 is a perfect correlation. This would indicate that the point was located in the exact same position each time they were measured. The value r^2 is a measure of the variance that can be explained by the normal variance within the group.

III. CHANGES OCCURRING IN THE CONTROL GROUP BY SEX

When comparing changes that occurred by sex in the control (non-treated) group of patients, only MNSK ($p=.045$) showed a significant difference between the male and female response to normal growth. MNSK

TABLE II

DESCRIPTIVE STATISTICS

(ASSESSING MEASUREMENT ERROR)

VARIABLE	FIRST TRACING MEAN	STD	SECOND TRACING MEAN	STD	P-VALUE
MXSK	3.79	2.64	3.71	2.63	.121
BUI	0.04	1.32	0.12	1.31	.411
TUI	-0.70	0.93	-0.69	1.14	.974
TLI	-0.39	0.42	-0.41	0.78	.902
BLI	2.88	1.58	2.73	1.79	.418
MNSK	5.59	3.50	5.62	3.84	.875
OB	-3.76	2.41	-3.78	2.92	.944
GO	-1.03	1.91	-0.90	1.91	.337
MPA	1.51	1.87	1.44	1.81	.664

TABLE III

DESCRIPTIVE STATISTICS

(ASSESSING TRACING ERROR)

VARIABLE	FIRST TRACING MEAN	STD	SECOND TRACING MEAN	STD	P-VALUE
MXSK	4.25	2.89	3.79	2.64	.518
BUI	-0.29	1.29	0.04	1.31	.230
TUI	-0.13	1.09	-0.70	0.93	.033 *
TLI	-1.29	2.28	-0.39	0.42	.193
BLI	3.45	2.63	2.88	1.58	.411
MNSK	5.62	3.89	5.59	3.50	.915
OB	-3.88	2.51	-3.76	2.41	.844
GO	-0.81	2.32	-1.04	1.88	.518
MPA	1.60	1.77	1.51	1.87	.719

* significant $p<.05$

TABLE IV

RELIABILITY COEFFICIENTS

(ASSESSING MEASUREMENT ERROR)

Measure	r	r^2
MXSK	.998	.997
BUI	.975	.951
TUI	.814	.662
TLI	.814	.662
BLI	.953	.909
MNSK	.992	.983
OB	.948	.898
GO	.977	.955
MPA	.965	.931

TABLE V

RELIABILITY COEFFICIENTS

(ASSESSING TRACING ERROR)

Measure	r	r^2
MXSK	.920	.789
BUI	.808	.652
TUI	.757	.573
TLI	.678	.459
BLI	.607	.369
MNSK	.978	.957
OB	.712	.507
GO	.889	.789
MPA	.913	.833

increased significantly ($p<.05$) more in males than in females. However, this was only marginally significant. Both males and females, regardless of facial type, showed similar changes with growth over time. All variables except gonial angle and mandibular plane angle increased with normal growth. In most cases, the bite stayed the same or worsened. Other than MNSK, there were little differences between the changes exhibited by males verses females in the control group.

IV CHANGES OCCURRING IN THE TREATED GROUP BY SEX

When comparing the response differences of the treated group by sex, the only significant difference ($p<.05$) was found in MNSK ($p=.028$). MNSK increased significantly more (1.4 times) in males treated with cervical headgear than females. Other than MNSK, the response of males and females to cervical pull headgear for the variables studied was not significantly different.

V. OVERALL CHANGES IN TREATED VS CONTROL GROUP

The use of cervical headgear result in significant changes in the variables tested when comparing the treated group to the control sample

(Table VI). MXSK showed highly significant differences ($p<.001$) between the treated and control group. The treated group had a much larger increase in MXSK.

Mandibular skeletal height (MNSK) changes were significantly ($p<.001$) (1.6 times) higher in the treated group. However, both groups showed an increase in MNSK.

Overbite (OB) decreased significantly ($p<.001$) in the treated group. On the average, overbite was reduced nearly 5mm. In the control group, overbite actually increased slightly.

Mandibular plane angle (MPA) showed a highly significant increase ($p<.001$) with treatment. MPA in the treated group increased an average of 1.31 degrees, whereas in the control group MPA decreased an average of .81 degrees. This is a difference of 2.12 degrees.

Overall there was significantly more ($p<.001$) downward bodily movement of the upper incisor (BUI) in the control group. The treated group on average exhibited in upper incisor intrusion of 2mm. This could be attributed to mechanical intrusion of the tooth by archwires.

There was significant tipping of the lower

TABLE VI

DESCRIPTIVE STATISTICS

Means and Standard Error of the Means Comparing Control and Treated Groups

Variable	Control Mean	Control SEM	Treated Mean	Treated SEM	T-test P Value
MXSK	2.51	0.27	4.18	0.35	.000***
BUI	1.16	0.31	-0.72	0.23	.000***
TUI	0.25	0.31	-0.01	0.25	.514
TLI	0.16	0.15	-0.71	0.28	.008**
BLI	2.58	0.29	2.77	0.34	.669
MNSK	3.78	0.43	6.20	0.46	.000***
OB	0.37	0.18	-4.86	0.30	.000***
GO	-1.69	0.39	-0.28	0.35	.009**
MPA	-0.81	0.29	1.31	0.31	.000***

all values in mm except GO and MPA in degrees
* significant p<.05
** significant p<.01
*** significant p<.001

incisor ($p<.01$), which could contribute to overbite correction, and the amount of tipping in the treated group was nearly twice as much as that found in the control group. There was no significant difference in the bodily movement of the lower incisor (BLI) or tipping of the upper incisor (TUI).

In summary, the use of cervical pull headgear produced a significant change in MXSK, BUI, TLI, MNSK, OB, GO, and MPA when compared to the control group.

VI. CHANGES IN THE CONTROL GROUP BY FACIAL FORM

A one-way analysis of variance showed no significant difference between different facial types. All facial types had a similar response to normal growth for the variables studied.

VII. CHANGES IN THE TREATED GROUP BY FACIAL FORM

In the treated group a significant difference ($p<.05$) was found between the facial form and change in MNSK (Table VII). A one-way ANOVA test revealed that there was a significant difference between the euryprosopic and mesoprosopic group (Table VIII). The leptoprosopic group's values were intermediate and were not significantly different from the other

TABLE VII

P VALUES FOR TREATMENT AND FACIAL FORM

VARIABLE	EURYPROSOPIC	MESOPROSOPIC	LEPTOPROSOPIC
MXSK	.018*	.003*	.019*
BUI	.008**	.006*	.002**
TUI	.721	.222	.071
TLI	.075	.150	.085
BLI	.733	.895	.405
MNSK	.012*	.066	.033*
OB	.000***	.000***	.000***
GO	.037*	.098	.287
MPA	.003**	.003**	.018*

* significant p<.05
** significant p<.01
*** significant p<.001

TABLE VIII

ONE-WAY ANOVA FOR TREATED AND FACIAL FORM

VARIABLE	P-VALUE	EURY-MESO	EURY-LEPTO	MESO-LEPTO
MXSK	.034*	YES	NO	NO
BUI	.131	NO	NO	NO
TUI	.049*	NO	NO	NO
TLI	.524	NO	NO	NO
BLI	.253	NO	NO	NO
MNSK	.189	NO	NO	NO
OB	.740	NO	NO	NO
GO	.452	NO	NO	NO
MPA	.819	NO	NO	NO

* significant $p<.05$

TABLE IX

P-VALUES FOR TWO WAY ANOVA

VARIABLE	TREATMENT	FACIAL TYPE	INTERACTION
MXSK	.000***	.014*	.260
BUI	.000***	.018*	.908
TUI	.684	.368	.050
TLI	.005	.335	.885
BLI	.400	.067	.905
MNSK	.000***	.042*	.514
OB	.000***	.551	.661
GO	.008**	.739	.487
MPA	.000***	.270	.281

* significant p<.05
** significant p<.01
*** significant p<.001

DISCUSSION

The purpose of this study was to examine the effect of cervical pull facebow headgear on the treatment of deep overbite. The treated group was examined as an entire group of pooled individuals, and was then divided into subgroups based on their facial type (Hrdlicka, 1947). Changes in selected variables were analyzed for their relative contribution to the correction of deep overbite in the three facial types studied. It was hoped that an understanding of how differences in facial type influence deep overbite correction would be learned, since it is widely held that individuals with different facial forms respond differently to orthodontic treatment and require different forms of management (Ricketts, 1960; Creekmore, 1967; Schudy, 1968).

The study utilized a slightly modified version of the analysis developed by Kishiyama (1987) to assess changes that occurred in the vertical dimension. Tooth movement, skeletal change and growth changes were measured and analyzed within a specific facial type, and between facial types. The sample consisted of 45 treated and 40 control subjects matched for deep overbite, facial type, age

and sex. The treated and control groups represented a closely matched population.

The experimental group was selected for a single orthodontic technique, cervical pull facebow headgear. Since all patients were treated non-extraction, the results of this study also reflect the influence of non-extraction therapy when correcting deep overbites with cervical pull headgear.

A two way analysis of variance was employed to examine the effect of each variable after controlling for the effect of the other variables. This is necessary in order to determine if interactions occur between treatment groups for the various facial types. If there are interactions, then the changes that occur can not be explained by a single factor, ie. treatment or facial form. Two way analysis of variance found no interactions occurring between facial type and treatment effect; therefore, the effect of one variable (facial type) is not dependant on the effect of the other variable studied (treatment), and the effects of treatment and facial form can be evaluated separately without concern for interactions.

Treatment Effects When Controlling for Normal Growth

The use of a matched control group affords an opportunity to adjust the results for changes that would normally have occurred with growth alone. The ability to do this is essential for precise understanding of the contribution treatment mechanics have made toward overbite correction.

Various authors believe that cervical pull headgear can affect significant changes in the maxillary complex (Ricketts, 1968; Contasti, 1982) (Fig 3., Table VI and IX). This study found that all facial types had a substantially greater downward movement of the maxilla with treatment compared to controls. As the maxillary skeletal length increased, the vertical length of the midface increased. The effect of downward maxillary skeletal movement would tend to increase (worsen) overbite, and make its correction more difficult. In the leptoprosopic (long and narrow face) individual there was approximately 1.5-2 times as much downward maxillary movement than in the mesoprosopic and euryprosopic groups. Schudy (1968) believed that facial type was important in determining response to treatment. Perhaps leptoprosopic individuals are more susceptible to increases in maxillary skeletal

length than other facial types. Consequently, greater efforts may be required in order to control maxillary vertical dimension in leptoprosopic individuals.

Bodily intrusion of the upper incisor (Fig. 4, Tables VI and XI), is considered by many a fundamental component to overbite correction (Merrifield, 1970; Burstone, 1977). All groups exhibited significant bodily intrusion of the upper incisors. Although this could not be attributed to the cervical pull headgear, it is most likely a result of the mechanics employed with archwires. It is interesting that the leptoprosopic individuals exhibited one-third greater bodily intrusion of the upper incisor than the other facial types. Is it possible that leptoprosopic individuals are more susceptible to upper incisor intrusion, or larger amounts of intrusion are necessary to offset the greater downward growth of the maxilla.

Although tipping of the upper incisor (Fig 5, Table XI) was not found to be significant, the euryprosopic and leptoprosopic facial types both exhibited some lingual incisor movement. In contrast, mesoprosopic individuals exhibited labial tipping of the upper incisor. This may be related to the sample type. It is possible that a

significant number of these individuals were Class II division II and the incisors were flared foward at the start of treatment in order to correct their linguoversion. Leptoprosopic individuals exhibited the greatest lingual uprighting. While this would tend to increase overbite, it would also decrease overjet. Graber (1954) in his study of patients treated with cervical pull headgear, found that in some severe class II cases treated with cervical pull headgear the maxillary incisors had tipped lingually in order to achieve a reduction of anterior overjet. While this would establish anterior incisal guidance, linguoversion of the maxillary incisors is not a desirable position.

All individuals exhibited labial tipping of the mandibular incisors with treatment (Fig. 6, Tables VI and XI). Euryprosopic individuals had the least, with mesoprosopic intermediate and leptoprosopic individuals exhibiting the most labial tipping. This is an interesting finding since one would expect that faces with a long vertical height would be finished with more upright incisors. It is possible that in order to achieve a favorable interincisal relationship, greater tipping of the lower incisors compensates for the tendency for clockwise rotation

of the mandible in leptoprosopic individuals.

Correction of deep overbite with bodily intrusion of lower incisors (Fig. 7, Table XI) has been advocated by many clinicians (Burstone, 1977; Ricketts, 1979). In all facial types, there was a small, yet insignificant, amount of extrusion of the lower incisor. Overall, the relative position of the lower incisors remained nearly unchanged. This is an unexpected finding, since intrusion of mandibular incisors is considered by many to be fundamental to overbite correction (Burstone, 1977; Ricketts, 1979) In this sample, intrusion of the lower incisors was not a significant contributor to overbite correction.

Mandibular skeletal height increased dramatically in the treated groups (Fig. 8, Table XI). The euryprosopic group exhibited the greatest increase in MNSK, followed by the leptoprosopic and mesoprosopic groups. It might be expected that individuals with longer faces (leptoprosopic) would have exhibited the greatest increase in MNSK. It appears that cervical pull headgear affected a greater increase in MNSK in short faced individuals than in long faced individuals. Another possible explanation may be that since euryprosopic individuals are shorter to start out with, they have

greater increase potential, or need greater increases in order to achieve good facial balance. One might expect that in euryprosopic individuals, strong muscular forces would inhibit increases in MNSK. Perhaps if treatment changes were examined at a later time, the stability of the changes could then be assessed (Melsen, 1978). It is interesting to find that the intermediate (mesoprosopic) facial type had the least amount of MNSK increase.

While gonial angle (M7) has been found to decrease with normal growth, patients treated with cervical pull headgear had an increased gonial angle when compared with controls for all facial types (euryprosopic > leptoprosopic > mesoprosopic)(Fig. 9, Table XI).

When analyzing changes in mandibular plane angle, cervical pull headgear was associated with an increase in MPA for all facial types (Fig. 10). Mandibular rotation has been studied by numerous authors (Kloehn, 1947; Newcomb, 1958; Poulton, 1967; Merrifield, 1970). Kloehn (1947) found no significant bite opening with cervical pull headgear due to mandibular rotation. Newcomb observed that mandibular plane would close subsequently if opened during treatment. Merrifield and Cross (1970) found

significant increases in mandibular plane angle in patients treated with cervical pull headgear. They believed that this was a very undesirable change. The findings indicate that all individuals exhibited substantial increases in MPA. The greatest increase occurred in the leptoprosopic group. Increases in vertical facial dimension are considered very undesirable in patients who are already long vertically. Leptoprosopic individuals exhibited an average net increase of 3.9 degrees. Euryprosopic individuals (those who could most tolerate an increase in MPA) exhibited an average net increase of 2.0 degrees. Mesoprosopic individuals exhibited the least mandibular plane opening, 1.4 degrees.

From the previous data, it appears that leptoprosopic individuals are most susceptible to clockwise rotations of the mandible with an increase in MPA. While this may be desirable in a euryprosopic individual (Ricketts, 1964), this would not be indicated in patients with long faces and large mandibular plane angles. This data substantiates the claim that patients with different facial types respond differently to orthodontic treatment (Ricketts, 1960; Creekmore, 1967; Schudy, 1968) and should be managed differently.

Bjork (1953) found that overbite tended to decrease with age when left untreated. In contrast, this study found that the severity of overbite stayed the same or increased slightly with age. However, whether this difference is significant is undetermined.

It is interesting that overbite decreased significantly in all patients treated with cervical pull headgear (Fig 11). On average, there was slightly more than 5mm of overbite reduction. All facial types exhibited a similar reduction, as there was no significant difference in overbite reduction between facial types. It appears that significant reductions in overbite can be accomplished with orthodontic treatment regardless of facial type.

Percent Contributions to Overbite Correction

The following discussion refers to the pie diagrams in figures 12, 13, 14, and 15, and tables X and XI. The values presented are corrected for normal growth, thereby allowing an assessment of the actual effect of treatment, without concern for growth.

In all groups, MXSK increased significantly. The percentage contribution to overbite change was

not favorable towards overbite correction. The leptoprosopic group showed the greatest contribution towards increase in overbite from maxillary skeletal increase. This is not surprising, since one would expect greatest vertical increases of MXSK to occur in long face individuals. This would indicate that extra effort should be expended in controlling vertical dimension (and associated maxillary molar extrusion) in leptoprosopic individuals.

Tipping of the upper incisors contributed negatively to overbite correction in euryprosopic and leptoprosopic facial types. In the leptoprosopic group, lingual tipping of the incisors accounted for nearly 13% of the contributions to change in overbite. This effect was negative. In mesoprosopic individuals, labial tipping accounted for 14% of the overbite change and contributed to its correction. Labial tipping of the lower incisors occurred in all groups and accounted for an average of 10% of the overbite change.

Bodily movement of the upper incisors accounted of average of 20 - 25% of overbite change. In all facial types, it appears that orthodontics was very effective in correcting deep overbite via intrusion of the maxillary incisors.

On average, labial tipping of the lower incisor accounted for approximately 12% contribution to overbite change (reduction). All facial types displayed labial tipping which probabley was the result of archwire forces. In addition to overbite correction, this would tend also affect a reduction in overjet.

Bodily movement of the lower incisors actually had an extrusive effect in all facial types. It appears that lower incisor intrusion was not a factor in the correction of overbite. In fact, the incisors extruded slightly in all cases. The mesoprosopic group displayed the greatest percent contribution for lower incisor extrusion (7.5%). It appears that with the large increases in vertical facial height in all facial types, lower incisor intrusion was not a significant factor in the reduction of overbite. Apparently, maxillary incisor intrusion was where correction due to incisor intrusion occurred.

In general, cervical pull headgear had a significant effect on increasing maxillary and mandibular skeletal height. The combination of upper incisor intrusion, labial tipping of the lower incisor and extrusion of posterior teeth is in agreement with Engel's (1980) assertion that overbite

correction is most likely the result of incisor intrusion and molar eruption. It appears that the net effect of all factors studied, both positive and negative, was a significant reduction in overbite.

Mandibular plane angle increased significantly in all groups. Many authors (Silverstein, 1954; Schudy, 1965; Poulton, 1967; Merrifield, 1970) believe that a clockwise rotation of the mandible is undesirable. However, this study could not accurately assess this, since molar relationship, overjet correction, facial appearance, and other factors must also be studied in order to properly assess overall treatment result.

TREATMENT EFFECTS AND BIOLOGICAL MECHANISMS OF GROWTH

It is important to examine the regional growth processes and the biological mechanisms that take place as an individual grows and develops in order to understand the changes that occurred with cervical pull headgear treatment. Without treatment an individuals' craniofacial form and pattern is maintained with growth. As an individual grows, remodeling (deposition and resorption) and displacement of the teeth and craniofacial structures maintains a functional equilibrium. Regional

imbalances often exist and compensate for each other in order to maintain normal growth. When the expression of these imbalances exceeds normal limits, an abnormal relationship will exist.

Orthodontic treatment is aimed at working with the natural growth process of an individual in order to affect the displacement of the craniofacial structures and alter the growth remodeling (deposition and resorption) of these structures and establish a new physiologic and functional equilibrium with good facial balance.

Cervical pull headgear produces downward and backward force vectors which are transmitted through the maxillary first molars to the dentition, maxilla, associated sutures, and distant craniofacial structures. During normal growth the maxilla and the nasomaxillary complex are carried downward by secondary displacement from the middle cranial fossa. Simultaneously, primary displacement occurs with downward movement of the nasomaxillary complex and sutural growth. Resorption on the nasal side and deposition on the oral side of the palate causes an inferior relocation of the maxilla, as well as providing rotational adjustments of palatal alignment in response to displacement rotations (includig those

caused by headgear).

The use of cervical pull headgear caused a significant increase in MXSK in all facial types. It is likely that the appliance augments the displacement of the entire nasomaxillary complex, causing remodeling changes in the size and shape of the entire maxilla and associated structures. The cervical pull headgear affects the sutures, causing a redirecting of the normal remodeling process.

It is probable that the the appliance also increases the size of the nasal cavity by increased resorption on the nasal side of the maxilla and deposition on the palatal side. Additionally, increased downward vertical drift of the teeth occurs with associated socket remodeling. In addition to vertical changes, horizontal changes also occur with headgear use. However, these changes were not assessed.

All patients exhibited significant bodily intrusion of the maxillary incisors. The maxillary incisors normally drift downward with growth and development. Forces from archwires are transmitted to the socket and cause remodeling and upward vertical displacement of the teeth. Simultaneously, as the maxilla is displaced downward, additional

intrusion of the teeth occurs, as the teeth are prevented from moving downward with normal growth, resulting in a net intrusive effect.

Lingual tipping of the maxillary and mandibular incisors is expected with normal growth. It is interesting that the mesoprosopic individual exhibited labial tipping of the upper incisor. This movement would be accompanied by a reversal of the normal remodeling process. Labial tipping would necessitate deposition on the labial alveolar surface of the anterior maxilla, normally resorptive, and resorption on the lingual surface, normally depository.

Labial tipping of the lower incisors was a common feature of all facial types. This would not be expected with normal growth and development, as the mandible relocates downward and foward. Normally, the mandibular incisors rotate lingually and drift vertically upward. This is associated with resorption of the labial alveolar surface and deposition on the lingual alveolar surface. With treatment, all facial types exhibited a reversal of this process, and associated labial tipping of the incisors.

There was no significant change in the vertical

position of the mandibular incisors between control and experimental. One might expect an attempt to intrude the incisors when opening the bite and an associated downward drift of the socket accompanied by intrusion of the incisors. However, it appears that this was not a mechanism of overbite correction in the individuals studied. As best, the vertical height of the mandibular incisors was maintained at approximately the same relative position and upward drift was prevented.

MNSK increased significantly in all groups. With normal growth, the vertical length of the face increase by: 1. a small amount of displacement by the downward growth of the middle cranial fossa, and 2. remodeling of the ramus and condyle which not only increases vertical length of the ramus, but also changes its vertical orientation. These factors result in a downward displacement of the mandible.

It is possible that as the maxilla moves downward under the influence of the headgear, the mandible is displaced and greater than usual amounts of remodeling occur at the inner and outer surfaces of the ramus and condyle. Growth becomes more vertically oriented. These changes can also be in response to changes in the functional occlusal plane.

However, changes in the functional occlusal plane were not investigated in this study.

Significant increases in the mandibular plane angle occurred in all facial types. This is unexpected since increases in the vertical height of the ramus would normally rotate the mandible and cause a decrease in mandibular plane angle. Similarly, the gonial angle increased (opened) in all facial types. Normally gonial angle would close in order to maintain the relationship of the maxillary and mandibular arches. Apparently, remodeling of the ramus was affected and this resulted in an opening of the gonial angle, which could account for some increase in MPA. It is interesting that mesoprosopic individuals had the least increase in MPA and gonial angle. Euryprosopic individuals had similar increases in both gonial angle and MPA. Leptoprosopic individuals had the greatest increase in MPA.

FACIAL TYPES

This study defined individuals on the basis of three facial types: euryprosopic, mesoprosopic, and leptoprosopic. It is conceivable that this is not a comprehensive classification because morphologic

differences exist between individuals within facial types. This may explain why some findings appear to be inconsistent with traditional beliefs. For example, euryprosopic individuals are usually associated with a low mandibular plane angle. However, some euryprosopic individuals had a high mandibular plane angle. It is possible that the use of three facial types is not a sensitive enough criterion to show differences within facial types. Perhaps groups should be defined differently in future studies. This may help explain individual variations that exist within facial types.

RELAPSE AND PHYSIOLOGIC REBOUND

This study examined the effects of cervical pull headgear over a relatively short time period (from the start of treatment to the removal of appliances). The goal of any orthodontic procedure is to affect a stable change in the direction and magnitude of displacement movement of the various growth centers, both soft and hard tissue. These clinical procedures introduce changes which affect the pre-existing balance of the malocclusion.

Relapse of the correction achieved with orthodontics is a significant concern for all

clinicians. Changes in the functional equilibrium of the different structural components require significant adaptation. If a given treatment procedure changes the relative position of the anatomic components, subsequent growth can cause rebound back toward the original position. It is possible that the changes in the variables studied are subject to physiologic rebound/relapse (Trouten, 1980; DiPalma, 1982), or may be affected by post-treatment growth. This study was unable to assess changes that occurred with subsequent growth and development. This would require examination of the individuals at a much later time interval, in order to assess the stability of the clinically induced alteration of growth and development. Some anatomic relationships are more resistant then others to a change in their existing direction of growth. Studying rebound/relapse would give insight into how resistant the existing anatomic relationships are to change, as well as differences between facial types and the influence of treatment timing.

TABLE X

SUMMARY OF SIGN CONVENTIONS

MXSK	
+	= upward movement anterior aspect of maxilla
_	= downward movement anterior aspect of maxilla
BUI	
+	= upper incisor intrusion
-	= upper incisor extrusion
TUI	
+	= labial tipping of upper incisor
-	= uprighting of upper incisor
TLI	
+	= labial tipping of lower incisor
_	= uprighting of lower incisor
BLI	
+	= lower incisor intrusion
-	= lower incisor extrusion
MNSK	
+	= downward movement anterior aspect of mandible-
-	= upward movement anterior aspect of mandible
OB	
+	= overbite increased
-	= overbite decreased
GO	
+	= gonial angle became more obtuse (opened)
-	= gonial angle became more acute (closed)
MPA	
+	= mandibular plane angle became more obtuse
-	= mandibular plane angle became more acute

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

TABLE XI

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

	E+M+L	EURYPROSOPIC	MESOPROSOPIC	LEPTOPROSOPIC
MXSK	-1.67	-1.47	-1.59	-3.24
BUI	+1.88	+1.99	+1.9	+2.32
TUI	+0.26	-0.23	+1.13	-1.26
TLI	+0.87	+0.74	+1.01	+1.19
BLI	-0.19	-0.26	-0.60	-0.13
MNSK	+2.42	+3.53	+1.82	+2.65
OB	-5.23	-5.78	-5.25	-4.78
GO*	1.41	2.39	0.87	1.50
MPA*	2.12	2.04	1.42	3.93

see Table X for summary of sign conventions
*in degrees

Figure 3. Bar graph depicting the mean for MXSK for each facial type. The treated sample is represented by bars on the right, while the corresponding control sample is represented by bars on the left.

VARIABLE – MXSK

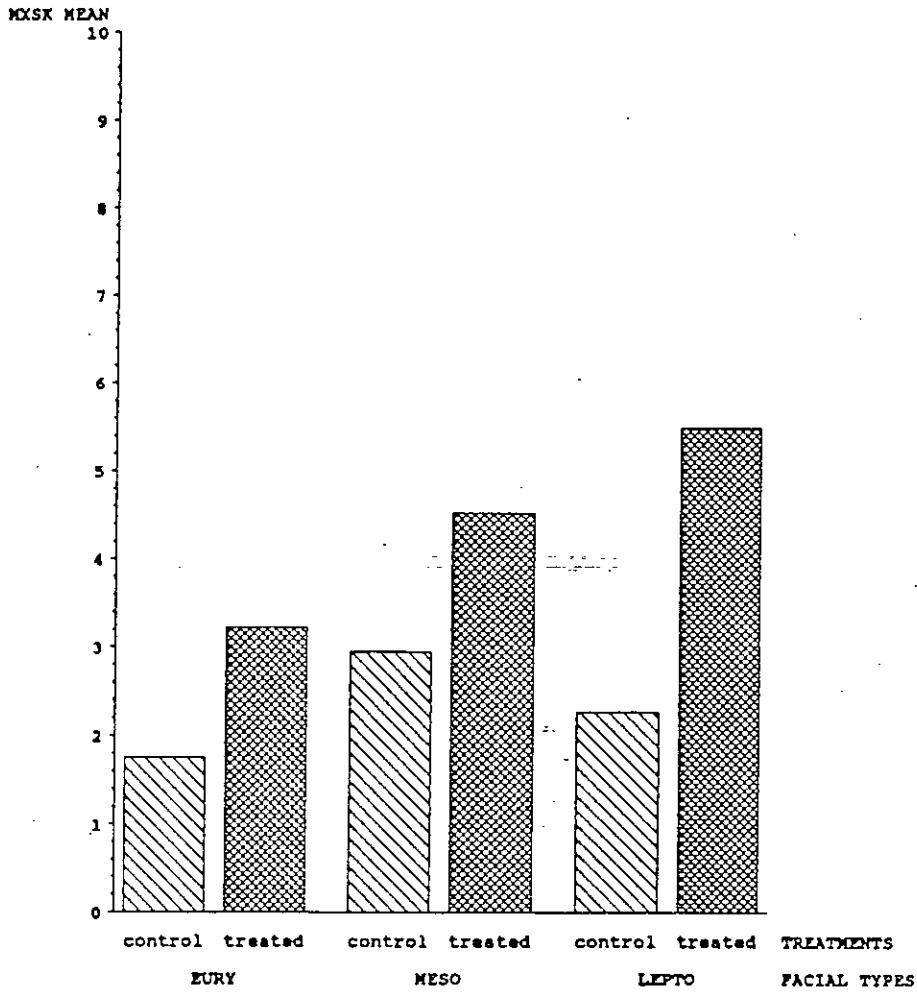


Figure 4. Bar graph depicting the mean for BUI for each facial type. The treated sample is represented by bars on the right, while the corresponding control sample is represented by bars on the left.

VARIABLE - BUI

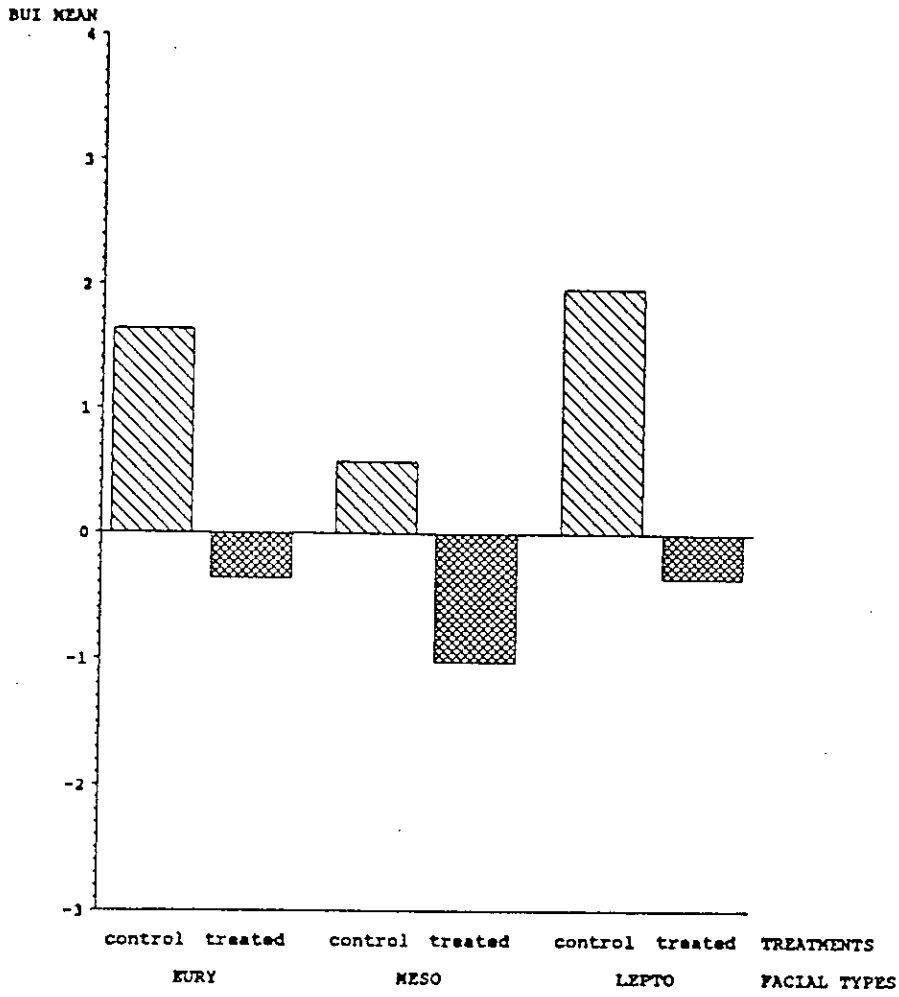


Figure 5. Bar graph depicting the mean for TUI for each facial type. The treated sample is represented by bars on the right, while the corresponding control sample is represented by bars on the left.

VARIABLE – TUI

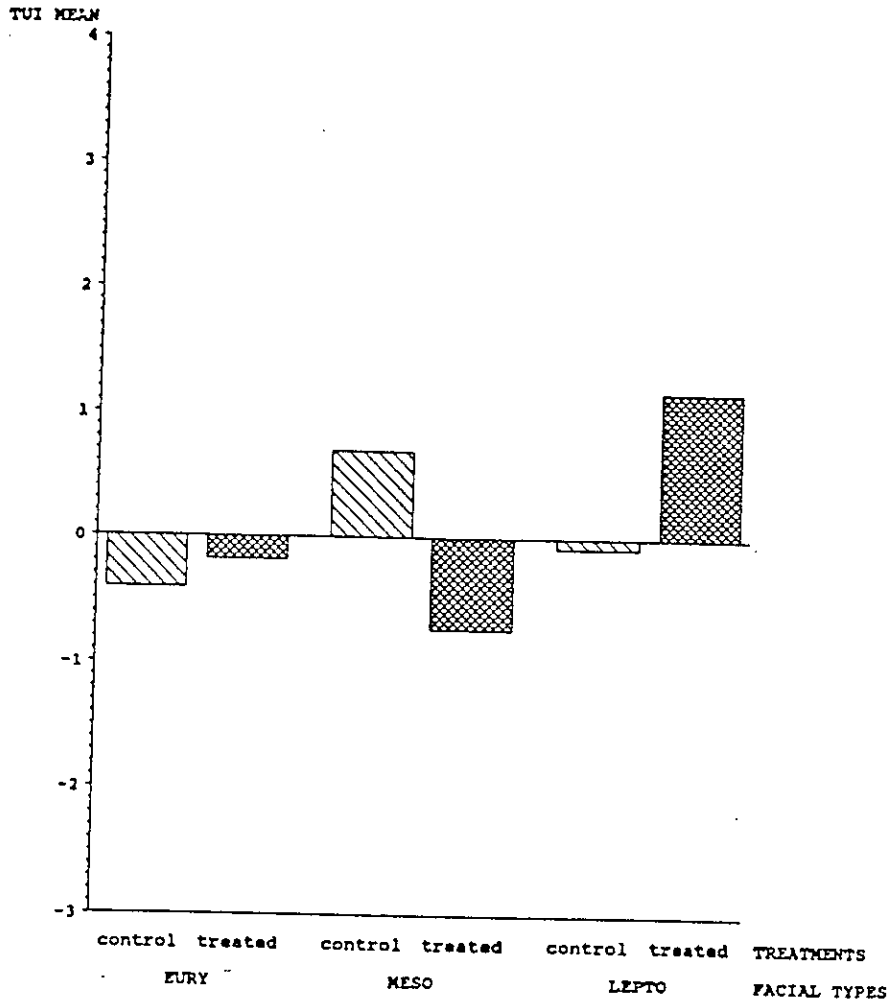


Figure 6. Bar graph depicting the mean for TLI for each facial type. The treated sample is represented by bars on the right, while the corresponding control sample is represented by bars on the left.

VARIABLE – TLI

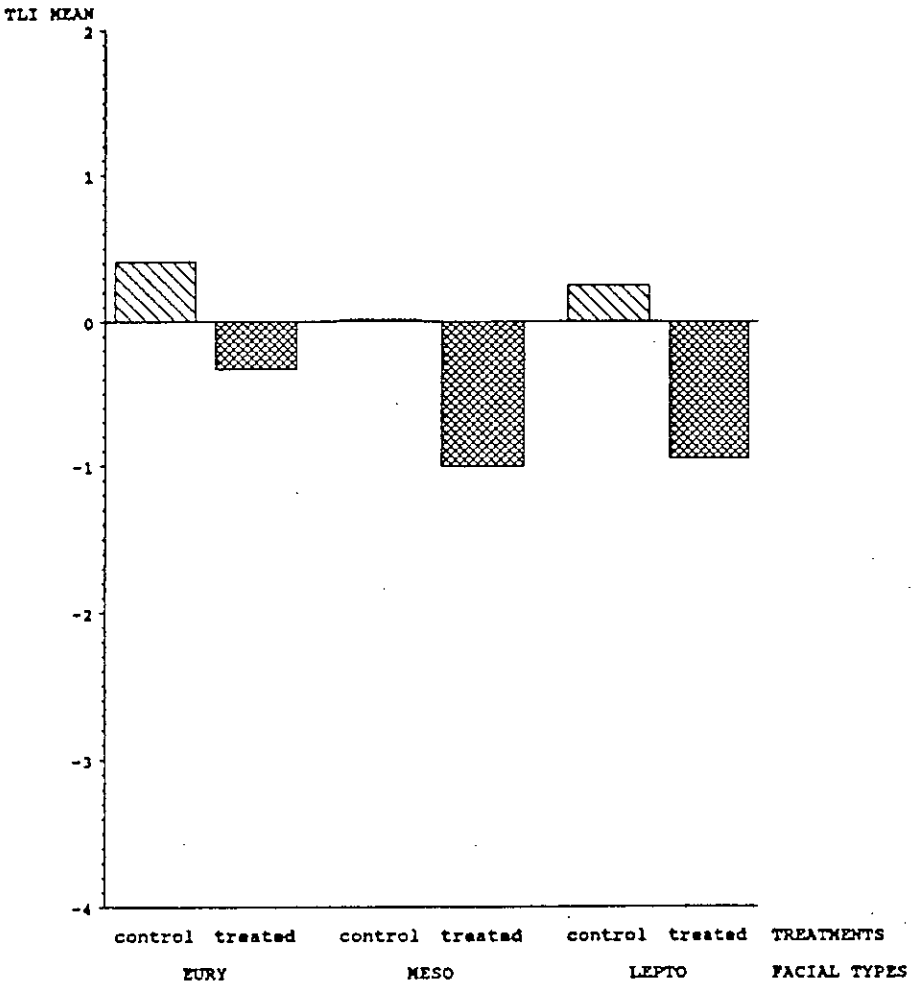


Figure 7. Bar graph depicting the mean for BLI for each facial type. The treated sample is represented by bars on the right, while the corresponding control sample is represented by bars on the left.

VARIABLE - BLI

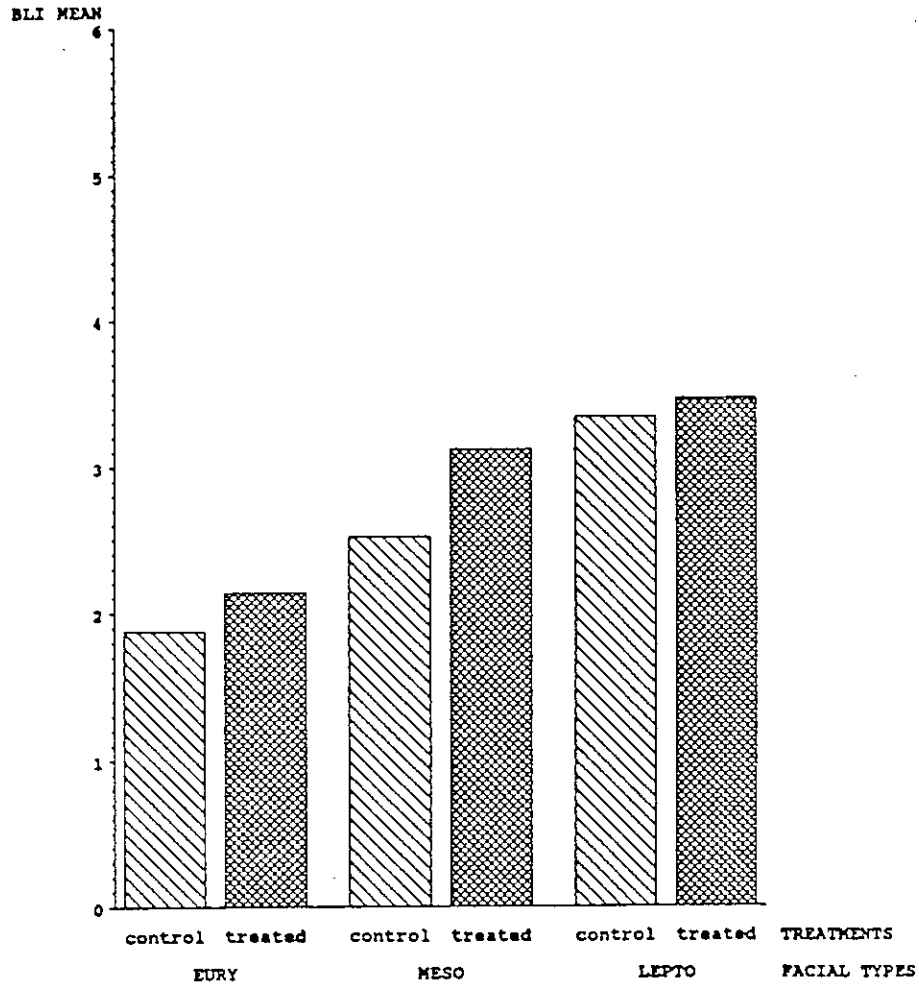


Figure 8. Bar graph depicting the mean for MNSK for each facial type. The treated sample is represented by bars on the right, while the corresponding control sample is represented by bars on the left.

VARIABLE - MNSK

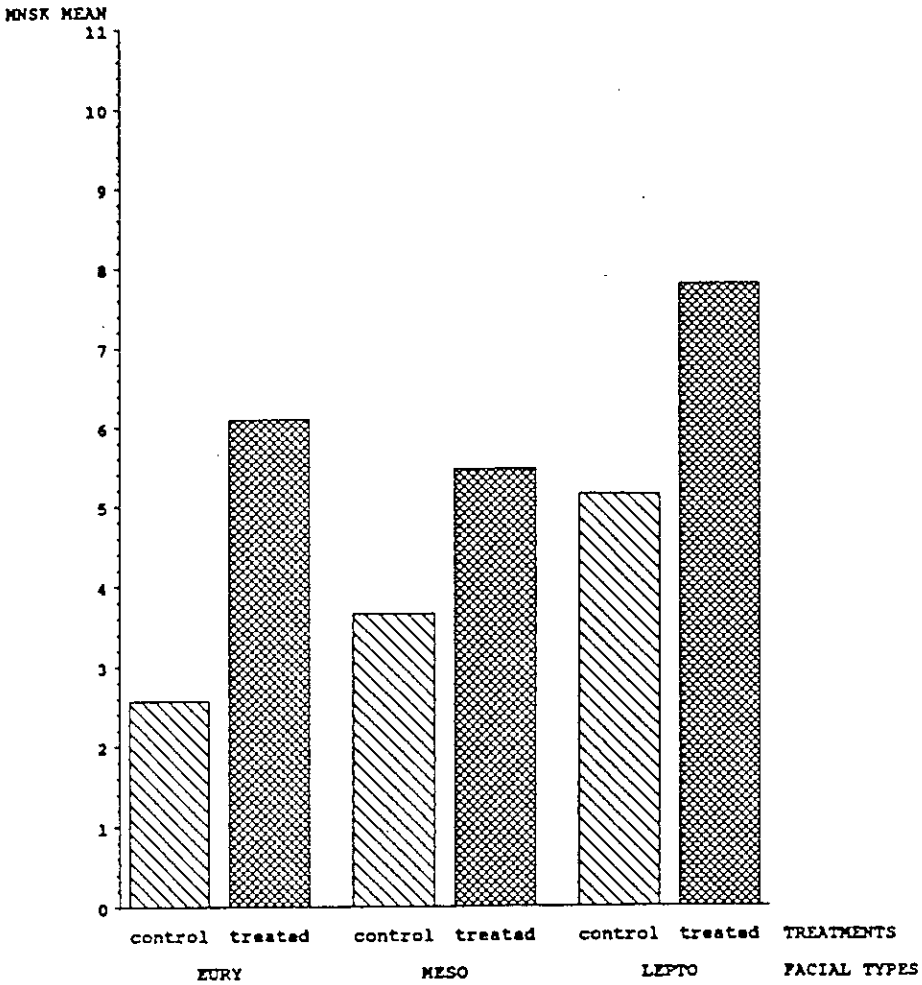


Figure 9. Bar graph depicting the mean for M7 (G0) for each facial type. The treated sample is represented by bars on the right, while the corresponding control sample is represented by bars on the left.

VARIABLE - M7

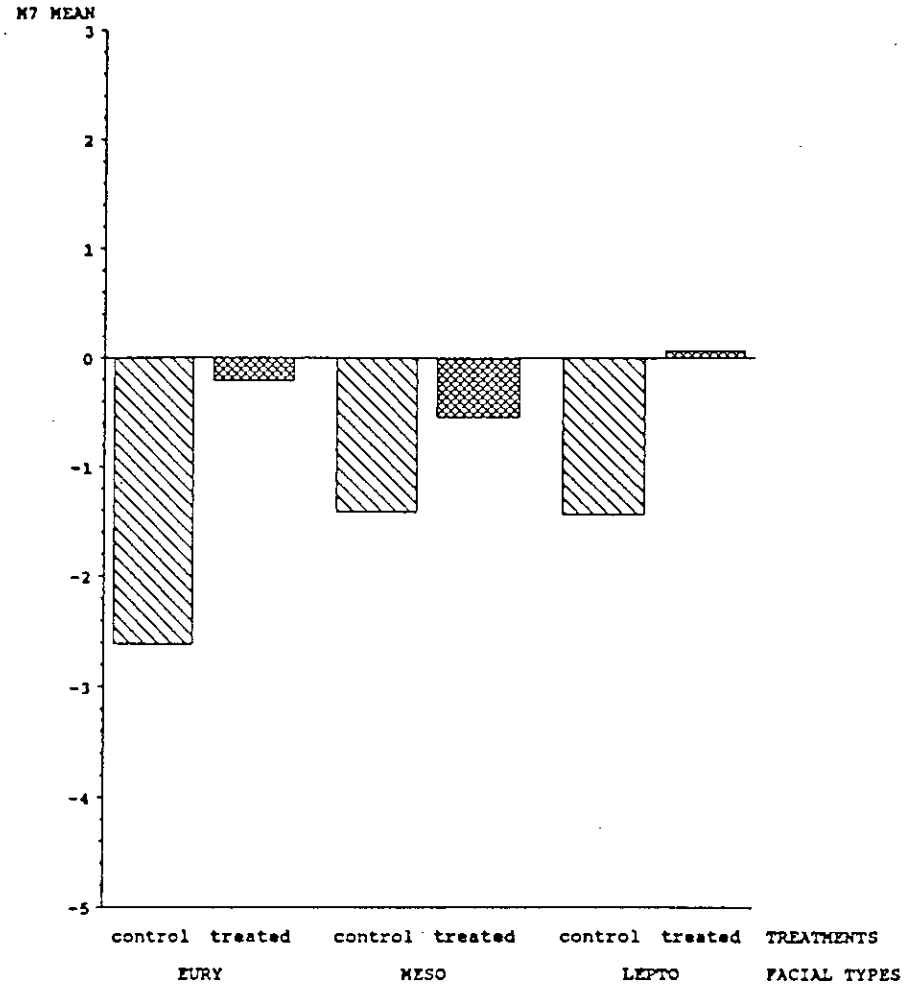

M7 MEAN
3
2
1
0
-1
-2
-3
-4
-5
control
treated
control
treated
control
treated
TREATMENTS
EURY
MESO
LEPTO
FACIAL TYPES

Figure 10. Bar graph depicting the mean for MPA for each facial type. The treated sample is represented by bars on the right, while the corresponding control sample is represented by bars on the left.

VARIABLE - MPA

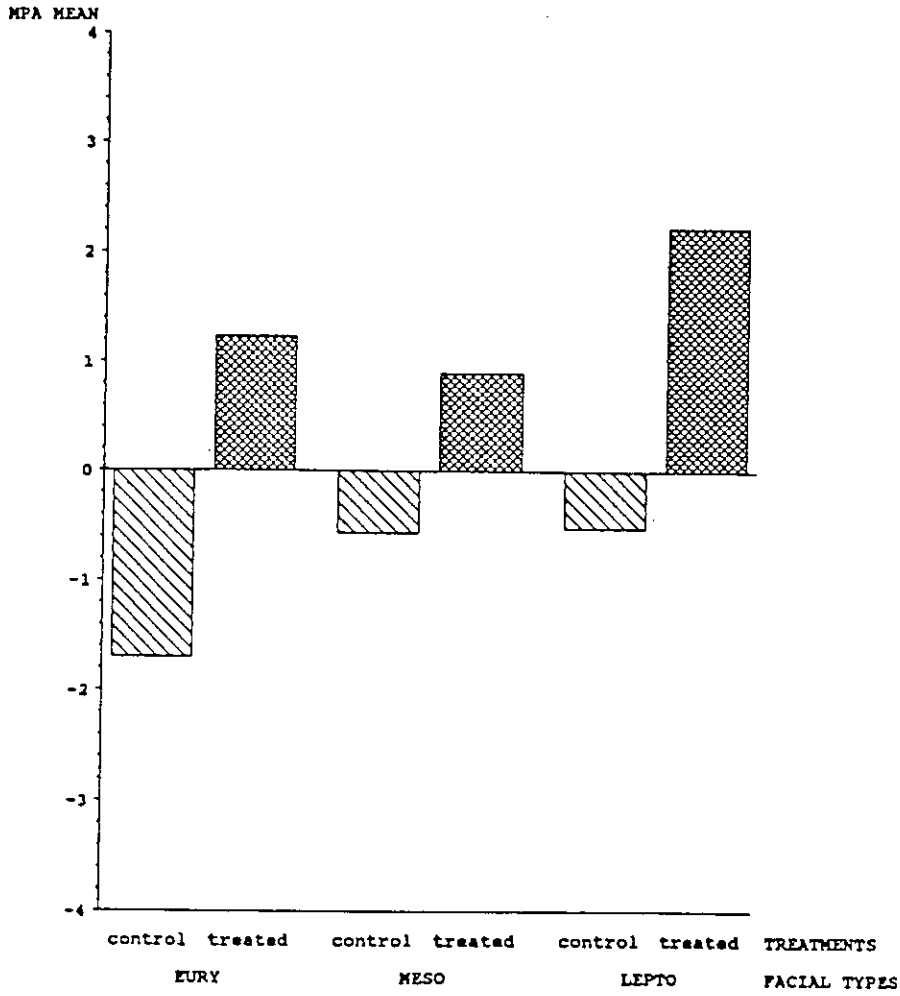


Figure 11. Bar graph depicting the mean for OB for each facial type. The treated sample is represented by bars on the right, while the corresponding control sample is represented by bars on the left.

VARIABLE - OB

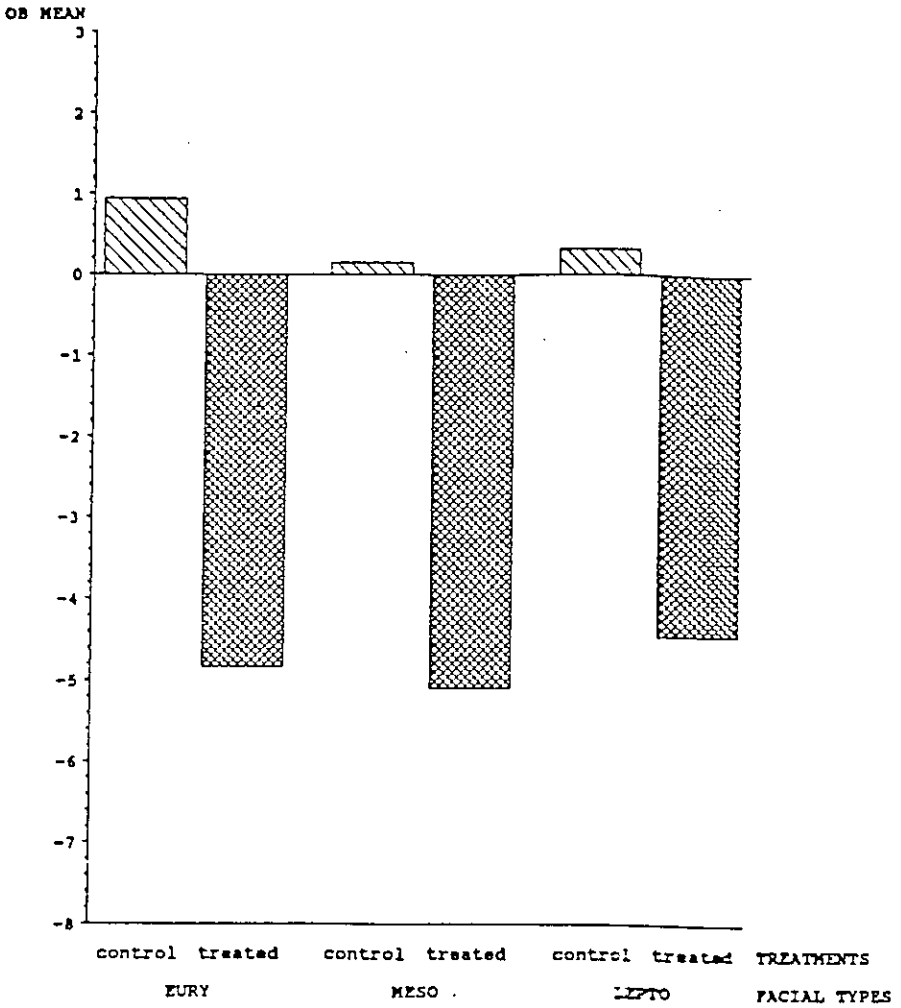
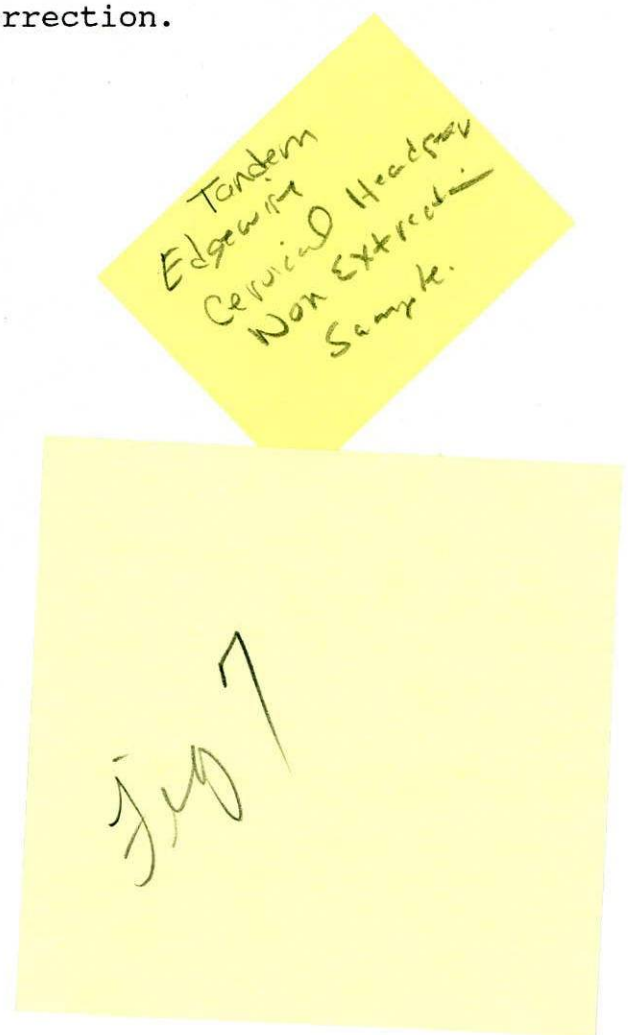

OB MEAN
3
2
1
0
-1
-2
-3
-4
-5
-6
-7
-8
control
treated
control
treated
control
treated
TREATMENTS
EURY
MESO
LEPTO
FACIAL TYPES

Figure 12. Pie diagram showing percentage contribution of each variable to overall mid- to lower anterior facial height change for all facial types. Stars represent negative or unfavorable contributions to overbite correction.



TREATED GROUP (E + M + L)

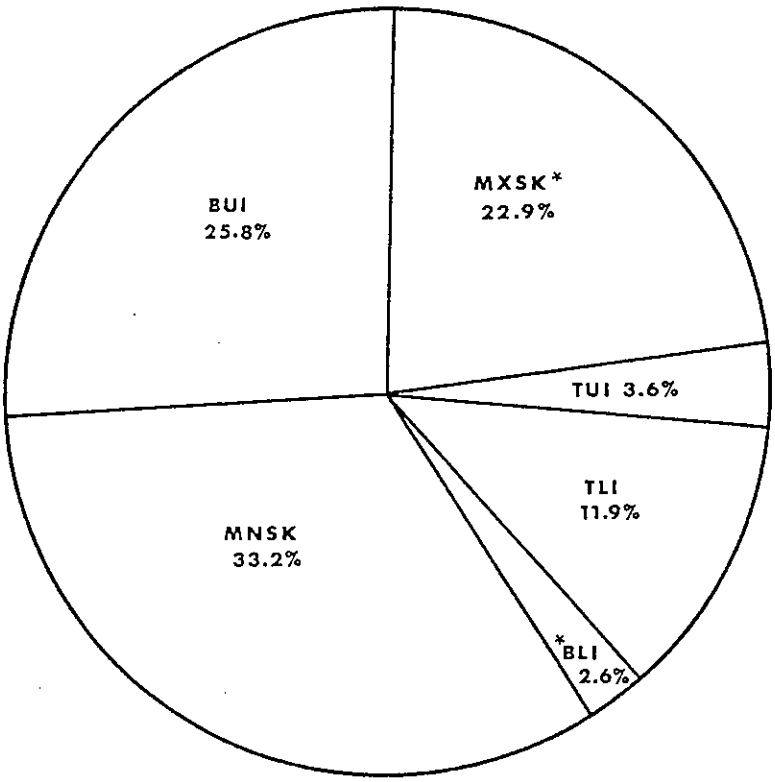


Figure 13. Pie diagram showing percentage contribution of each variable to overall mid- to lower anterior facial height change for euryprosopic facial types. Stars represent negative or unfavorable contributions to overbite correction.

EURYPROSOPIC

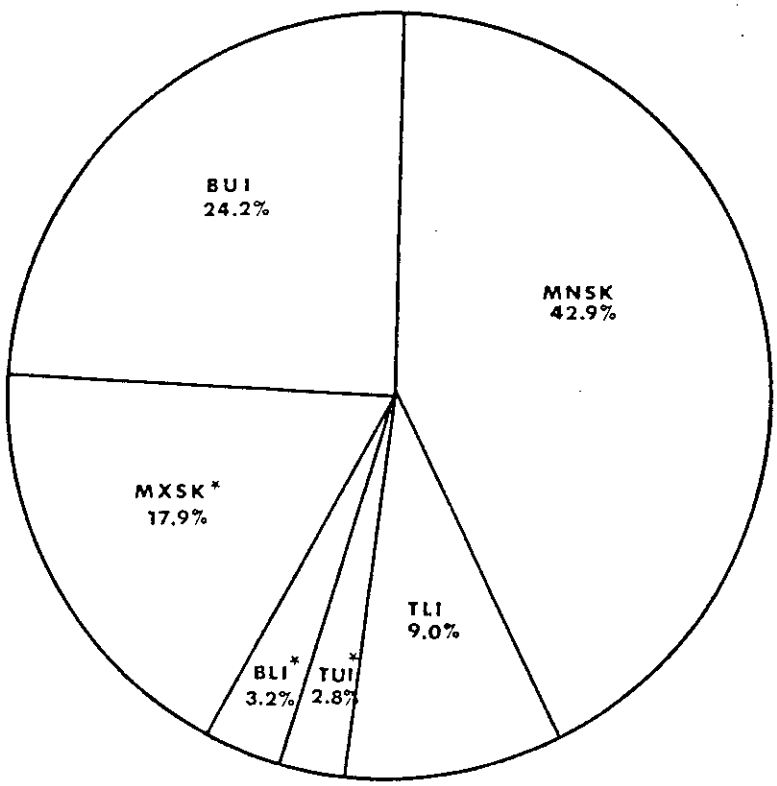


Figure 14. Pie diagram showing percentage contribution of each variable to overall mid- to lower anterior facial height change for mesoprosopic facial types. Stars represent negative or unfavorable contributions to overbite correction.

MESOPROSOPIC

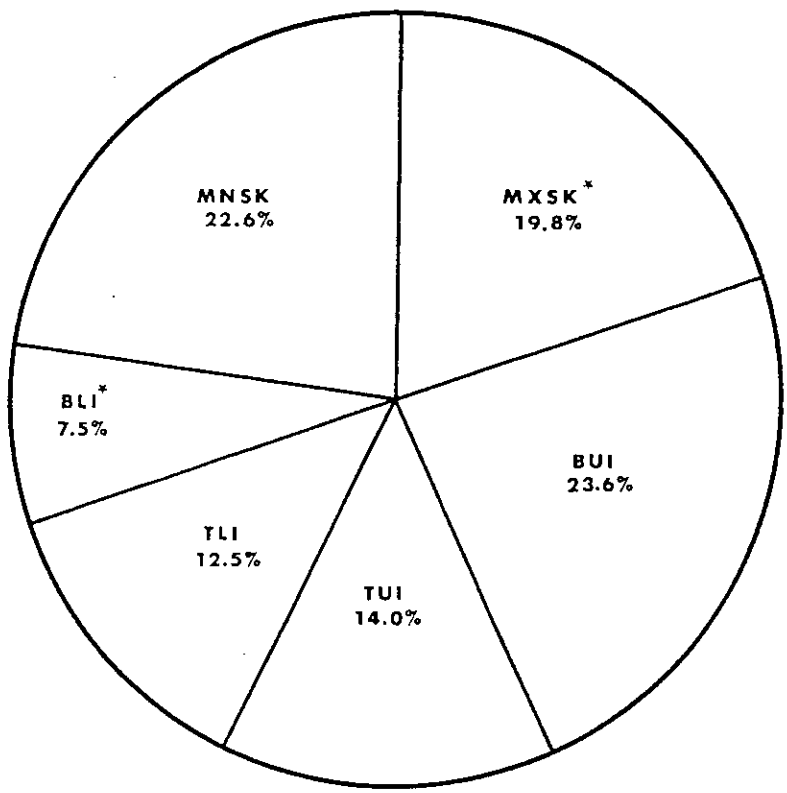
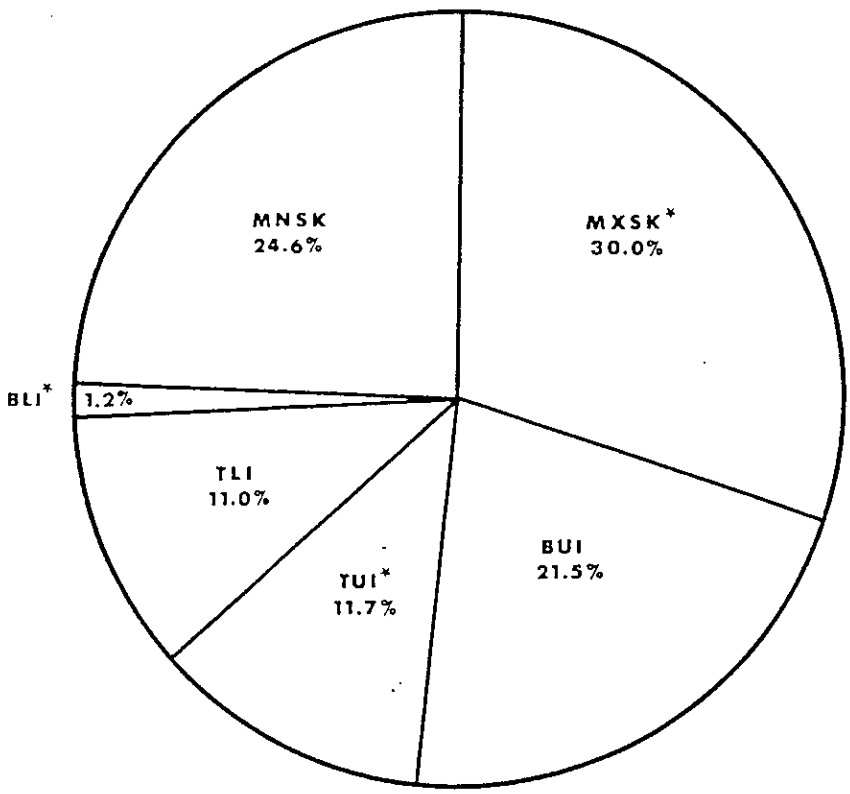


Figure 15. Pie diagram showing percentage contribution of each variable to overall mid- to lower anterior facial height change for leptoprosopic facial types. Stars represent negative or unfavorable contributions to overbite correction.

LEPTOPROSOPIC



SUMMARY AND CONCLUSIONS

The purpose of this study was to evaluate the correction of deep overbite with cervical pull facebow headgear and the effect of facial type on treatment response. The sample consisted of 45 deepbite patients treated with cervical pull (Kloehn-type) facebow headgear. A control group of 40 untreated patients were selected from the Bolton Study (Cleveland, Ohio) according to the same criterion (deep overbite and adequate initial (T1, C1) and deband (T2, C2) cephalograms). The treated and control groups were matched for age, sex, and facial type. Thus, the experimental and control groups represented a similar population. Facial type was determined according to the anthropometric classification of facial indices by Hrdlicka (1947).

Tracings were made of the headfilms and values calculated. Statistical analysis of the data was done in order to assess changes that occurred. The following observations were made:

1. Significant correction of overbite was achieved in all facial types. While the three facial types exhibited differences in the percent each factor contributed to overbite reduction, all groups showed a similar amount of overbite reduction.

2. The only significant difference between males and females was seen in mandibular skeletal height. Males showed a

significantly greater increase in MNSK with treatment than females. This is not surprising, since males tend to exhibit more mandibular growth than females. Males may be more susceptible to increases in lower facial vertical height. Otherwise, males and females responded similarly to treatment with cervical pull headgear for the variables studied.

3. The use of cervical pull facebow headgear significantly increased the length of the midface, MXSK, when compared to the control group. This effect is probably not desirable in long face individuals.

4. A significant percent of overbite correction came from bodily intrusion of the upper incisor. Conversely, bodily intrusion of the lower incisor was not a contributor to overbite correction.

5. There was no significant amount of tipping of the maxillary nor mandibular incisors. This may be related to the fact that none of the patients had extractions.

6. Although all facial types exhibited large increases in mandibular skeletal height (MNSK), only the extreme facial types, euryprosopic and leptoprosopic, exhibited significant increases in MNSK. One might expect the smallest increase in MNSK to occur in the euryprosopic group. This group actually had the largest increase in MNSK. The mesoprosopic group had the least increase in MNSK. This substantiates the efficacy of cervical pull facebow headgear in short faced individuals that need bite opening. Additionally, control of vertical dimension in long faced individuals may be indicated in avoid unwanted vertical increases.

7. Cervical pull facebow headgear increased mandibular plane angle significantly in all facial types. Leptoprosopic individuals had the greatest increase in MPA. Increases in MPA result in a downward and backwards (clockwise) rotation of the mandible, often

considered an undesirable change.

8. In euryprosopic individuals, MNSK was the single largest contributor to overbite correction (47.9%). In both meso- and leptoprosopic individuals, MNSK and BUI equally contributed to overbite reduction and accounted for most of the correction.

9. Two way analysis of variance (ANOVA) showed that no interactions occurred between facial types and treatment effect. Therefore, the effect of either treatment or facial type could be considered separately, without concern for interactions.

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49 91 393CS 104 TH
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4293