Cephalometric Evaluation of Using Anterior Bite Elevators in Growing Patients with Deep Bites

by

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DEDICATION

To my father, my role model who made me into the person I am today. To my beloved mother, who sacrificed all so that her children could have no more. And to my grandmother, I am I am so grateful to still have you around us. To my brother, your friendship and encouragement have always been a source of inspiration to me. You all mean the world to me!

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ABSTRACT

Objective: The purpose of this study is to cephalometrically evaluate the effects of anterior bite elevator mechanics used concurrently with a pre-adjusted edgewise appliance in treatment of growing patients with deep bites. **Materials and Methods:** A total of 60 pre and post-treatment lateral cephalometric radiographs were retrospectively collected for our sample of 30 patients who were treated consecutively with anterior bite elevators by the same orthodontist. Thirty controls selected from the Bolton Brush Growth Study were matched on age, gender and Angle malocclusion. All radiographs were oriented, traced, superimposed and measured by the same examiner, using a commercially available imaging software program (Dolphin). The CWRU vertical analysis was utilized to characterize the dental and skeletal changes. The following variables were evaluated; maxillary skeletal change (MXSK), bodily movement of upper incisor (BUI), tipping of upper incisor (TUI), tipping of lower incisor (TLI), bodily movement of lower incisor (BLI), mandibular skeletal change (MNSK) and overbite change. In addition, gonial angle (GA) and mandibular plane angle (MPA) were measured. **Results:** Significant skeletal and dental changes ($p \leq 0.001$) were noted among the variables assessed between both treated and control groups. Even with no treatment, control group showed skeletal changes and minimal dental movements. Among the variables that didn't show significant difference were MXSK and GA. **Conclusions:** Deep overbite correction was achieved efficiently using anterior bite elevators in conjunction with edge

wise appliance compared to matching control group. Significant bodily and tipping movements of upper and lower incisors contributed to overbite reduction although the most significant contributor was increasing lower facial height presumably by eruption of the posterior teeth.

Keywords: Deep bite, anterior bite elevators, bite turbos, cephalometrics, CWRU analysis

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Review of Literature

Overbite Epidemiology / Etiology

From initial eras of orthodontics, overbite has been one of the commonest evils that we meet (Callaway in 1940). Deep overbite has been a frequently encountered malocclusion in orthodontic practices, it has been found to be associated with abnormal mandibular function; TMJ disorders, and has potentially detrimental effects on mandibular development in severe deep bite cases. The common definition of overbite was developed by Strang (1934) who defined it as "the overlapping of the upper anterior teeth over the lowers in the vertical plane." He referred to excessive overbite as a deleterious form of malocclusion that affects the longevity of the dentition.

Normal overbite has been measured in percentages, millimeters and sometimes relative to certain anatomical relationships. As reported by Neff in 1949, ideal overbite was measured at 20% vertical overlap between upper and lower incisors, while others have recorded it to be a range between 35 to 40%, for example, Williamson in 1976 who explained ideal vertical relationship to be accomplished when incisal edges of the lower incisors are resting against the cingula of the upper incisors. In 1952, Steadman reported a range of 0.5 mm to 4.3 mm with a mean of 3.1 mm (standard deviation of 1.9 mm) to be considered as an ideal overbite, Ricketts in 1982 found a mean value of 2.5 mm to be optimal per his studies on ideal dental and skeletal relationships.

According to the requirements of a healthy functional occlusion an overbite was defined to be extreme when the lower incisor edge is beyond the cingula of the upper incisor. As stated by Profitt et al (1998), deep bite malocclusion (overbite ≥5 mm) has a prevalence of 20% in children and 13% in adults, while 14% have an overbite less than or equal to zero and less than 1% of the population have severe open bite (negative overbite ≥ 2 mm), suggesting a high prevalence of malocclusions characterized by excessive overbite in our society based on the estimates from the NHANES III survey. Individuals with deep overbites are more prone to future oral diseases and potential danger to the dental arch integrity (Mershon 1937).

Proffit et al in 2013 reported that different ethnic groups demonstrate conspicuous variations in vertical dental relationships; African Americans and Hispanics show almost half the prevalence of severe deep bite (overbite ≥5 mm) as compared to Caucasians ($p \leq .001$). And the total opposite was found regarding anteroposterior problems, which are more prevalent in Hispanics than other ethnicities. On the other hand open bites are 5 times more common in African Americans than in Caucasians and Hispanics. They also added that vertical deviations from the ideal overbite (0 to 2 mm) are more frequent in children than adults with the great majority of who possess an excessive overbite.

Deep overbite is a multifactorial type of malocclusion that can be attributed to skeletal, dental and/or neuromuscular factors. In 1925,

Campbell studied dental casts and found that overbite varies significantly from one individual to another due to differences in the depth of the cusps of the molars and bicuspids. Steadman (1949) used plaster casts from a sample of individuals with acceptable anterior overbite. He found a positive correlation between interincisal angle and anterior overbite. Popovich (1955) reported similar findings and concluded that a directly proportional relationship exists between the interincisal angle and the anterior overbite.

The cause of excessive anterior overbite can be due to many factors, Mershon tried to identify those in 1937. He categorized deep bites into two main groups; a true closed bite, which is due to infraocclusion of posterior segments and heavy forces of strong oral musculature, making deep overbite correction a challenging task. And second group of deep bites characterized by over erupted anterior teeth, which can be successfully treated with intrusion.

In 1928, Grieve stated that deep anterior overbite relationship was related to the anteroposterior discrepancy caused by protrusion of maxillary teeth, a deficient mandible or both. Prakash and Margolis (1952) conducted a cephalometric study showing another positive correlation between maxillary incisors' height and overbite and a negative correlation between eruption of mandibular molars and overbite. More recently, Proffit (1992) stated that deep overbite results from over eruption of lower anteriors, especially in cases with mandibular retrognathia.

In different studies conducted by Strang (1934) and Hemley (1938),

they both found an association between the development of deep overbite and problems in posterior/anterior vertical tooth eruption. They also implicated muscular forces in molar infraocclusion and incisor supraocclusion causing deep overbite. Carlyle (1977) reported that there was no correlation between increased incisor dento-alveolar vertical height and deep overbite. He showed that the association was only exclusive to dento-alveolar vertical molar height, retrusive lower incisors and a retrognathic mandible relative to maxilla as well as the cranial base.

Sassouni and Nanda (1964) summarized several factors related to deep anterior overbite that were cited by others. Among those dental factors were large cusp heights of posterior teeth, short molar height, upright incisors and increase in freeway space. While for skeletal variables that are associated with deep overbite, they stated acute gonial angle, decreased total anterior facial height as well as short anterior lower facial height and horizontal palatal-occlusal-mandibular planes. They also concluded that imbalances in the vertical dimension were more significant and should be addressed first to efficiently correct the anteroposterior discrepancies.

Theories of muscle attachment and forces have always been linked to skeletal open and deep bites. In 1967, Nanda et al concluded that the muscles of mastication exerted different levels of function and of force vectors in each type of malocclusion. In deep bite cases, the muscular forces are directed more anterior and more perpendicular, delivering more

force over the molars resulting in infra-eruption. Along the same lines, in 1971 Moss and Salentijn believed that the masseter muscle position is normal but the capsule surrounding the muscle was found atypical in deep skeletal deep bites.

To test these muscular theories, Proctor and DeVincenzo in 1970 conducted a cephalometric study where they located the anterior border of the masseter muscle by palpation followed by positioning .020 inch wire on the patients, directly superficial to the masseter muscle border while taking their lateral cephalograms. They found that the open bite subjects demonstrated a more horizontal orientation of the masseter relative to SN, Frankfort and palatal planes yet more vertically inclined musculature related to the mandibular plane. And concluded that there is no difference in the attachment sites of the masseter muscle in skeletal open and deep bites. Also found no inter-group differences between muscle inclination and occlusal plane in open and closed bite subjects.

While Barton found that the neuromuscular features played a major role and concluded that muscular forces eventually determined the extent of posterior and anterior teeth eruption in 1972. Popovich in his cephalometric study (1955) attributed class I malocclusion with deep overbite more to dental factors while on the other hand in class II malocclusions, skeletal factors as short ramus and facial height in conjunction with secondary dental factors were thought to be the main contributor to developing excessive anterior overbite.

More recently, in a sample of 124 El-Dawlatly et al (2012) performed various measurements on pretreatment study casts and cephalometric radiographs trying to identify main factors behind deep overbite. They found that etiology can be of skeletal or dental origin; vertical facial type, mandibular ramus height or gonial angle are the major skeletal factors with the latter being the highest contributing factor to a deep bite. Deep curve of spee (most common), over-eruption of the maxillary incisors, lingual inclinations of the maxillary and mandibular incisors or molar infra-occlusion are the contributing dental factors.

In 2013, Ghafari et al. attributed the etiology of deep bite to heredity and development unlike open bite, which has been more related to pathologic factors or parafunctional habits. They supported the genetic theory behind this type of malocclusion by the features that usually occur with Class II division 2. Prevalence of dental anomalies and delayed dental development are favoring the theory that overbite is majorly yet not exclusively controlled by genetics. That being said, they concluded that we should not treat deep bite cases to intercept the etiology but to avoid it from worsening during development.

Skeletal Growth and Dental Overbite

Many researchers (Bjork 1953, Moorrees 1959, Herness et al 1973 and Moyers 1976) have studied the changes in the amount of anterior overbite with growth and there is still lack of agreement among them. Overbites have been reported to increase, decrease and sometimes remain at the same plateau with age. Due to marked individual variability as well as wide range of values, investigators could not reach a consensus regarding effect of age when they evaluate overbite changes. Baume observed in 1950 that deficient forward growth of the mandible during incisor tooth eruption was associated with deep overbite. He also concluded that the sagittal (anteroposterior) mandibular growth was important in determining vertical overbite.

In 1944, Diamond studied vertical development of the mandibular ramus and its correlation to dental height. He found that deficient growth in the length of the ramus would retard the active eruption of the posterior dental segments and allow continuous eruption of the anterior dental segments resulting in excessive overbite. McNamara stated in 1986 that in an adolescent patient with normal growth and development, we should expect one-degree decrease of mandibular plane angle every three to four years, thus having a bite closing effect.

In his longitudinal study, Bjork in 1953 followed the variation of growth occurring between the ages of twelve and twenty years old. He found that during growth there is a tendency for general decrease in the

overlap of anterior teeth and that deep overbites tend to open more than normal overbites despite individual variations. And with Skeiller, both implicated that mandibular growth rotations can either increase or decrease overbite depending on anti-clockwise or clockwise rotations (1972).

Fleming conducted a cephalometric and plaster model study in 1961, he found a significant negative correlation between ramus length and degree of overbite. So, he attributed excessive overbite to mandibular ramus height. In 1963, Schudy found association between ramus height increase and deepening of the anterior overbite. His sample involved deep overbites with class II due to mandibular retrognathia and large rami. And in his 1968 study, he concluded that downward maxillary growth accounts for more than two thirds of total facial vertical growth, which is established to be an important factor affecting dental overbite and lower facial height.

In 1969, Richardson examined lateral cephalometric radiographs of 110 deep overbite as well as 110 open bite subjects. The upper facial heights were almost matching but there was a decrease in lower facial height in the deep overbite cases compared to the open bite cases. He also reported that as the ramus height and mandibular body length increased, the jaw angle compensated by closing and the lower facial height was maintained or slightly decreased. He collaborated with Moss and Salentijin in 1971 and found in their study that the shape of the mandible to be more important than its size or dimension in excessive

overbite cases.

Naumann et al (2000) stated in their study that despite the large discrepancy that exists between maxillary and mandibular skeletal displacement during adolescence growth, overbite remains relatively stable throughout growth to support the concept of vertical dento-alveolar compensatory mechanisms. Their multivariate model on a longitudinal sample of 181 French Canadian children showed that although the average overbite changes between 10 and 15 years were minimal (0.2 mm), variation ranged from 2.4 mm of bite opening to 5.6 mm of bite deepening. They concluded that vertical/rotational mandibular changes are more important than maxillary changes in determining overbite changes.

McDowell et al (1970) found that vertical changes would be balanced by relatively stable vertical growth in patients with normal mandibular plane angle during orthodontic treatment. On the average, the molars were extruded 4.7 mm in the grower's group. However, the mandibular plane angles did not change during treatment. This finding can be attributed to the greater amount of posterior mandibular development that was observed in growing patients. Even with minimal extrusion of the molars (1.3 mm on average), the adults did not maintain the original mandibular plane angle. Although the main etiology remains as a controversy in our specialty, many orthodontists such as Schudy (1964), Bench (1977) and Engel (1980) believed that facial types categorized according to lower facial height, Y-axis as well as other indicators as FMA,

SN-MP, OM angles can predict how favorable or unfavorable the individual's response would be.

In his study entitled "morphologic factors in open bite and deep bite", Trouten in 1980 used Enlow's counterpart analysis to study normal, untreated deep overbite and open bite cases. He reported the following traits in deep overbite subjects; a closed gonial angle, flat mandibular and occlusal planes, deep curve of spee and decreased palatal depth, greater maxillary protrusive tendency, less posteriorly aligned ramus and upward corpus-occlusal rotation in relation to the ramus rotation. Questioning Angle's class I vs Class II malocclusions, he found no significant difference between the two groups.

In a more recent study, Baccetti et al (2011) studied the longitudinal growth changes in growing deep bite subjects. Their sample comprised of 29 subjects that were monitored over a period of 9 years. They noticed significant prepubertal deepening of the anterior bite followed by an average of 1.3 mm improvement at the pubertal growth spurt, mostly due to vertical mandibular growth at the ramus followed by mandibular molars eruption. Finally concluded that results might help us as clinicians for better treatment timing although skeletal vertical relationships couldn't forecast excessive overbite improvement during their observation.

The term "hypodivergent" and "hyperdivergent" were coined by Schudy in 1964 to describe low and high angles cases, respectively. He found that the hypodivergent facial type was characterized by a low

mandibular plane angle, decreased facial height and decreased occlusal-mandibular angle. The opposite features were found for hyperdivergent subjects. Moreover in his studies, Schudy believed that determining an individual's response to treatment is more dependent on the facial type than the amount of dental overbite present.

Wylie (1946) and Ricketts (1960) had a consensus that malocclusion is dependent on various facial forms. Different facial forms react differently to orthodontic treatment and that each form needs special approach for treatment. In 1947, Bjork found an inversely proportion relationship between depth of overbite and occlusal-mandibular plane angle. Ludwig (1967) concluded in his 5 mm or more deep overbite sample that there was no significant correlation between facial patterns and pretreatment overbite, which contradicts the findings of other studies as Schudy's, which showed the amount of overbite is always related to the facial form.

Creekmore in 1967 evaluated the effects of orthodontic treatment on vertical development of the face. In his study, he involved untreated controls and treated cases to find that vertical eruption is not uniform. In comparison, the orthodontically treated sample showed significant extrusion of the mandibular molars and relative intrusion or inhibition of the mandibular incisors plus he found that vertical dimension and facial form increased as the bite opened. He also reported that high angle cases will more likely develop vertically without orthodontic intervention than the

other average facial types. And the opposite is true for low angle patients, which might suffer gradual increase in deep bite without any orthodontic intervention.

In additional studies, to explore the influence of facial type during orthodontic treatment of excessive overbite, Ricketts believed that wider symphyses in brachycephalic patients allow for easier intrusion of lower incisors and there was a higher success rate in those low mandibular angle individuals compared to dolichocephalic cases with ling thin symphyses. Bench et al in 1978 stated that high angle patterns were characterized by narrow symphyses and labially tipped lower incisors, which results in challenging intrusion mechanics while on the other hand low angle subjects with more squared symphyses and wider mandibular alveolus allowed for better incisor positioning and hence more efficient intrusion during orthodontic correction.

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

For short faces, molar extrusion has always been advocated by Ricketts (1960) and Burstone (1977) as they both felt it is beneficial for

those patients to decrease their deep overbite simultaneously with increasing the lower facial third height as well as reducing chin prominence by allowing the chin downwards and backwards. They also believed that this approach should be avoided in long faces, as it would worsen the patients' profile. However it is more controversial in average facial patterns whether to extrude posterior segments versus incisors intrusion.

Different Treatment Approaches

Efficient correction of deep overbite is one of the primary objectives of comprehensive orthodontic treatment and hence various orthodontic appliances have been utilized to achieve that. To mention a few, there are functional/orthopedic appliances as cervical pull / J-hook headgears, bionator, activator, anterior bite plane, etc. Other orthodontic protocols would be intrusion arches, reverse curve of spee wires, anchor bends, etc.

A classic article by Schudy stated that anterior dental height holds the key for overbite correction and that success of the overbite correction is assured if distance from anterior nasal spine (ANS) to menton (Me) increases during treatment by extruding molars and avoiding incisors intrusion. He mentioned that vertical overbite is mainly affected by the downward displacement of the maxilla during growth which subsequently after the lower facial height. In his study an occlusal to mandibular plane of 21 degrees or above was a good indicator for maintaining overbite correction versus poor prognosis of 7 degrees or lower.

Otto in 1980 described that overbite reduction included more than intrusion alone, it involved increased facial height along with labial flaring of the incisors during treatment, to be the main elements of deep overbite correction. He also added that neither age nor facial type had any influence upon the amount of incisor intrusion although review of this study revealed a suspect sample size and experimental design.

It's always been a debate whether it's better to extrude premolars/molars and rotate the mandible open as the treatment of choice proposed by Schudy (1963), Creekmore (1967), Dave and Sinclair (1989). Or to follow Ricketts (1960), Burstone (1977) and DiGiulio (1983) who have long been an advocate of treatment of deep bites through intrusion of incisors, particularly lower incisors.

In 1980 Engel, et al. summarized four orthodontic approaches for deep bite treatment including premolars extrusion to level the curve of spee in the lower arch, secondly intrusion and or proclination of the incisors; and lastly molars extrusion. He stated that during orthodontic treatment of deep overbite cases, growth can be advantageous if controlled properly. In certain orthodontic mechanics if not all, overbite correction probably occurs from a combination of molar extrusion, incisor intrusion, labial flaring and jaw rotation.

When deep overbite treatment is targeted in teenagers, facial growth as well as several other factors as incisors display and lower facial height have to be taken into consideration compared to non-growing adults

with no vertical ramal growth. Extrusion of posterior and middle buccal segments is always a treatment of choice in growing patients with reduced lower facial third. Since during normal growth, the vertical distance between maxilla and mandible tends to increase, it is useful to count on it while opening an excessive overbite in growing patients. As it is widely accepted that correction of deep bite is both easier to accomplish and more stable when it is performed on growing patients than when it is attempted on those with no appreciable growth remaining.

The treatment of deep bite produced skeletal and dental changes that were statistically significant regardless of the mechanics used, and it primarily affected the inclination of incisors as well as the vertical position of molars. This was concluded by Parker et al. in 1995 in their retrospective study of a sample of 132 orthodontic patients as they were comparing six different modalities to correct deep bite. Another cephalometric study compared two different modalities for upper incisors intrusion in adults. A sample of 45 deepbite subjects was categorized into Connecticut intrusion arch, mini-implant system and control groups. They concluded that successful and efficient intrusion occurred in the treated groups although the CT intrusion group experienced some antero-posterior and vertical anchorage loss of the maxillary molars compared to the TADs and control groups (Senisik et al 2012).

Chua in 1993 examined the effects of extraction and non-extraction orthodontic treatments on the growth of the lower anterior facial height. A

sample of 174 patients was divided evenly into class I and class II malocclusions, where they used a linear cephalometric measurement from ANS to Me for each case at T1 and T2. They factored out growth by normalizing the same vertical measurement to the Michigan Growth Standard. Results showed that non-extraction treatment in both class I and class II subjects significantly increased the lower facial height and is associated with the downward and backward rotation of the mandible. They concluded that despite our beliefs, extraction treatment was not related to any changes in the lower anterior facial height suggesting that extraction alone is not effective in decreasing the lower anterior facial height.

In 2012, Baccetti et al investigated early versus late orthodontic treatment of anterior deep bites. They conducted their prospective clinical trial in Italy to compare outcomes in prepubertal and pubertal subjects with overbite of 4 mm or more. Protocol for early treatment group was either removable biteplane only or with cervical pull headgear followed by fixed pre-adjusted appliance after full permanent dentition, late treatment sample had same protocol except that they had full fixed appliance right after biteplane therapy. Results showed that overbite reduction occurred due to dento-alveolar changes only with no skeletal modifications as phase 1 had no significant effect on the vertical dimension of posterior facial height as well as mandibular rami. Values ranged between 2.7 to 4.7 mm of remaining overbite after treatment with significantly noticed relapse after discontinuing biteplane therapy.

Anterior Bite Plate

Since its introduction in the orthodontic practice in 1880, bite plates have been used as an adjunct in treatment of excessive anterior overbite. Different experienced orthodontists have primarily used it to help open the bite but no consensus has been reached regarding its mechanics. A sharp variance of opinion concerning the bite plate's induced changes, once school of thought developed by Mershon (1937) insists that it mainly causes depression or intrusion of lower anterior teeth with no eruption effect on the posterior dentition. On the other hand, Hemley (1938) among others totally believed that it's only elevation of molars and premolars that occur during orthodontic treatment using bite plates.

A quantitative analytic study done by Belger in 1956 using cephalometric radiographs of a total of 47 subjects was conducted to evaluate the physiologic vertical growth. Three categorized groups were included in the study, 25 controls, 12 treated with bite plates only and third group of only 10 subjects treated with bite plates together with other orthodontic appliances. He concluded that height increase due to growth only was predominantly at the mandibular molars and premolar region more than their maxillary counterpart. The bite plate sample had more height increase in the upper premolars and lower first molars, he explained the lack of maxillary molars eruption due to the bite plate's clasp. While the third group showed more eruption of the mandibular dentition than their maxillary counterpart.

In another study conducted by Menezes in 1975, his objective was to evaluate the changes in the dentofacial complex after bite plane therapy of 37 subjects with angle Class II, Division 1 malocclsuion. Dentofacial assessment was carried by means of lateral cephalomertic measurements on both the treated and control groups for a short and long term periods. He concluded that the main contributor for overbite reduction was increase in the molar height and subsequently increase the vertical dimension of the face, which might not have been achieved by normal facial development and growth.

A sample of 20 randomly selected Class II malocclusion growing subjects with deep impinging overbite was investigated by Forsberg et al (1984) after treatment by means of a fixed lingual arch with anterior bite plane. Vertical separation between molars was recorded at 4 mm just after appliance insertion, they gained occlusal contacts between molars in an average of 3.6 months. After comparing the treated group with a control sample, they reported acceleration of the vertical development of the mandibular posterior dentition and also found that retardation of vertical development of the upper face height. According to their cephalometric assessment, they concluded that overbite reduction was achieved due to anterior rotation of maxilla and posterior rotation of mandible with lower anterior facial height increase.

Hellsing et al investigated a smaller sample of eight in 1996, it was a radiographic study aiming at evaluating the effect of a fixed anterior bite

plane therapy on subjects with temporomandibular dysfunction. Their protocol of treatment was 3.5-5 months of maxillary palatal arch with anterior bite plane followed by edgewise appliance to secure the overbite reduction. They believed that muscle relaxation was achieved due to the fixed bite plane therapy and thus pain free joint during treatment, they added that occlusal stability is a fundamental criteria to completely eliminate any future recurrence of TMD symptoms. In their opinion, anteroposterior discrepancy correction is also required to maintain and stabilize the overbite reduction achieved post-treatment.

Philippe (1996) mentioned that during his five years' experience using bonded biteplanes, he observed that his patients' speech can be slightly affected for a short period of time as well as for chewing and mastication with no TMD symptoms reported by his patients during treatment. He observed that molar contacts were achieved after three to four months of treatment with anterior biteplane in growing subjects while 4 to 6 months in adults. Moreover he advised to keep biteplanes in place until posterior settling with normal incisor relationship are achieved.

Bahador and Higley (1944) conducted a study on 20 patients with deep overbite to improve their function, prevent incisal wear, facilitate restorative work, eliminate trauma and improve general appearance. They concluded that within their uncontrolled sample, various amount of bite opening was obtained and very few of them showed slight lower incisors intrusion. Most vertical correction was due to increase of molar eruption

especially maxillary molars, with majority of those cases showing lower facial height changes accompanied by mandibular retrusion.

Recently, there are treatment modalities as anterior bite elevators (turbos) used to reduce the depth of the bite, they are gaining popularity among clinicians and are being utilized more routinely nowadays since introduced to the orthodontic market. They offer a more tolerable and convenient alternative to orthodontic patients compared to their conventional bulky predecessor, anterior bite planes; moreover they don't require patients' compliance in contrast with removable bite planes.

Similarly clear aligner company known as Invisalign® introduced to the market in 2013 a solution for anterior deep bite using their precision bite ramps. Their 5th generation aligner material offered a horizontal plastic extension on the palatal surface of maxillary incisors for up to 3 mm depth to disocclude posterior dentiton and allowing correction of excessive anterior overlap. Few clinical studies were conducted to demonstrate invisalign capabilities in managing overbites (Giancotti et al 2008 and Khosravi et al 2017 and Shin 2017). But as of now there has been no clinical studies on how efficient or effective are the mechanics of utilizing the G5 virtual ramps solely in reducing deep bites.

Vertical Tooth Movement Assessment

In order to properly evaluate the vertical incisor movements, we must be aware of the different interpretations and definitions of either intrusion or extrusion. Thurow in 1962 stated that as the mandibular

incisors are tipped forward, the incisal edges will also tip downward on the arc of rotation, thus clinically appearing as if the tooth was intruded. He called this movement “tipping depression”. Later on, McDowell (1970) defined true intrusion as the bodily translatory movement of the tooth in the socket while Burstone (1977) termed the labial tipping of an incisor around its centroid as pseudo-intrusion.

Sassouni and Nanda explained tooth depression in growing adolescent as in relation to growth, they elaborated that by holding the tooth while the alveolar process is still growing occlusally, it showed that relative depression of that tooth. Although an established definition of genuine intrusion was stated as the translation of incisors along their long axes, Liu and Herschleb (1981) defined tooth movement by their horizontal and vertical components within a coordinate system as well as axial inclination. They recommended their definition as pure intrusion consisting of pure vertical displacement of the center of resistance where the axial inclination of the tooth stays constant.

Creekmore (1967) and Parker (1995) used perpendicular lines from ANS to U1 incisal edge and mandibular plane to L1 incisal edge to measure the vertical behavior of the maxillary and mandibular incisors, respectively. In their study mentioned above, Liu and Herschleb (1981) used and a cephalometric analysis that involved measuring intrusion from the center of resistance, located as 40% of the root length. And root length was measured as the distance from the alveolar bone to the root apex.

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

Otto in 1980 studied the effects of a bioprogressive technique on the intrusion of incisors according to different facial types. Templates were used to trace the incisors by registering on the incisal edge and aligning to the long axis allowing uniform transferring of tooth position. After superimposition, measurements at the root apices were calculated to evaluate amount of intrusion as well as long axis of tipping changes. This technique was intended to evaluate bodily intrusion at the apex, which is less affected by tipping but suffers from apical root resorption.

In 1994, Kishiyama and Hans evaluated 45 cases treated with cervical pull headgear and 50 cases treated with bionator appliance in comparison with untreated 95 control subjects from the Bolton Study. They designed a unique cephalometric analysis to precisely isolate vertical tooth and skeletal movements in those deep bite cases according to different facial types. They transferred fiducial lines from T1 to T2 after superimposition of both lateral cephalograms and then measured 6 linear and 2 angular measurements. They concluded that deep overbite correction in headgear group was achieved by intrusion of U1 and vertical increase in mandibular skeletal. While bionator sample had relative

intrusion of U1 and L1 plus increase in mandibular skeletal change.

Following the same lines, Hans et al (2006) investigated two different orthodontic approaches using same cephalometric analysis designed by Kishiyama (1994). First group of 30 patients were treated with standard edgewise mechanics and 4 first molars extraction and the other group comprised of 31 patients treated with tweed edgewise mechanics and 4 first premolars extractions. They concluded that both strategies showed minimal changes in vertical facial height due to good control of vertical mandibular height during orthodontic treatment.

A different cepahlometric analysis was utilized by Alkumru et al in 2007 based on 9 angular and 11 linear measurements in their retrospective study. They performed overall and regional superimpositions as proposed by Bjork and Skieller, 1983 and Broadbent, 1937. Angle class I patients were treated by 4 first premolar extraction using Begg mechanics while Class II were treated with Begg intra-oral distalization arches with no extractions and were both compared to control group. They found all groups exhibiting similar Jarabak, anterior and posterior facial heights, while mandibular plane angle was significantly different in distalization group compared to the control.

Another extraction vs non-extraction study was conducted to cephalometrically assess vertical dentofacial changes in class I normo-divergent subjects. For cephalometric calibration, they used a coordinate system with Frankfort horizontal plane and a mandibular fiduciary line.

They found that the extraction sample of 31 patients had equal or even more increase in linear vertical dimensions as the 29 non-extraction patients. Their study did not support “the wedge hypothesis” as they believed that teeth extraction didn’t lead to either increase of overbite or MPA decrease (Valiathan et al 2008).

In a more recent study, Rozzi et al (2017) combined digital model analysis with cephalometrics to evaluate effects of leveling curve of spee in deep bite patients different skeletal vertical patterns. Their sample was 90 caucasians with 2 mm or more curve of spee depth categorized into low-, normal- and high-angle groups. Results showed that proclination and intrusion of lower incisors were the main contributors for leveling curve of spee in low-angle patients. While high-angle subjects achieved leveling through extrusion and uprighting of the posterior dentition.

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Statement of Thesis

The purpose of this study was to cephalometrically evaluate the vertical dento-alveolar and skeletal effects of anterior bite elevators mechanics used concurrently with pre-adjusted edgewise appliances in treatment of growing patients with deep bites. The treated group was recruited from a single private practice (Marissa Keesler, Neenah, WI) and matched to untreated control sample collected from the Bolton Brush Growth Study Center (Cleveland Ohio).

Null Hypothesis: Anterior bite elevator mechanics has no significant dento-alveolar effects in deep bite growing patients, when compared to untreated growing controls.

Alternative Hypothesis: Anterior bite elevator mechanics has significant dento-alveolar effects in deep bite growing patients, when compared to untreated growing controls.

Cephalometric Evaluation Of Using Anterior Bite Elevators In Growing Patients With Deep Bites

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Introduction

From initial eras of orthodontics, overbite has been one of the commonest evils that we meet (Callaway in 1940). Deep overbite has been a frequently encountered malocclusion in orthodontic practices, it has been found to be associated with abnormal mandibular function; TMJ disorders, and has potentially detrimental effects on mandibular development in severe deep bite cases. The common definition of overbite was developed by Strang (1934) who defined it as "the overlapping of the upper anterior teeth over the lowers in the vertical plane." He referred to excessive overbite as a deleterious form of malocclusion that affects the longevity of the dentition.

Normal overbite has been measured in percentages, millimeters and sometimes relative to certain anatomical relationships. As reported by Neff in 1949, ideal overbite was measured at 20% vertical overlap between upper and lower incisors, while others have recorded it to be a range between 35 to 40% as Williamson in 1976 who explained ideal vertical relationship to be accomplished when incisal edges of the lower incisors are resting against the cingulum of the upper incisors. In 1952, Steadman reported a range of 0.5 mm to 4.3 mm with a mean of 3.1 mm (standard deviation of 1.9 mm) to be considered as an ideal overbite, Ricketts in 1982 found a mean value of 2.5 mm to be optimal per his studies on ideal dental and skeletal relationships.

Deep overbite is a multifactorial type of malocclusion that can be

attributed to skeletal, dental and/or neuromuscular factors. In 1925, Campbell studied dental casts and found that overbite varies significantly from one individual to another due to differences in the depth of the cusps of the molars and bicuspids. Steadman (1949) used plaster casts from a sample of individuals with acceptable anterior overbite. He found a positive correlation between interincisal angle and anterior overbite. Popovich (1955) reported similar findings and concluded that a directly proportional relationship exists between the interincisal angle and the anterior overbite.

The cause of excessive anterior overbite can be due to many factors, Mershon tried to identify those in 1937. He categorized deep bites into two main groups; a true closed bite, which is due to infraocclusion of posterior segments and heavy forces of strong oral musculature, making deep overbite correction a challenging task. And second group of deep bites characterized by over erupted anterior teeth, which can be successfully treated with intrusion.

Theories of muscle attachment and forces have always been linked to skeletal open and deep bites. In 1964, Sassouni and Nanda concluded that the muscles of mastication exerted different levels of function and of force vectors in each type of malocclusion. In deep bite cases, the muscular forces are directed more anterior and more perpendicular, delivering more force over the molars resulting in infra-eruption. Along the same lines, in 1971 Moss and Salentijn believed that the masseter muscle position is normal but the capsule surrounding the muscle was found

atypical in deep skeletal deep bites.

In 2013, Ghafari et al attributed the etiology of deep bite to heredity and development unlike open bite that has been more related to pathologic factors or parafunctional habits. They supported the genetic theory behind this type of malocclusion by the features that usually occur with Class II division 2. Prevalence of dental anomalies and delayed dental development are favoring the theory that overbite is majorly yet not exclusively controlled by genetics. That being said, they concluded that we should not treat deep bite cases to intercept the etiology but to avoid it from worsening during development.

Efficient correction of deep overbite is one of the primary objectives of comprehensive orthodontic treatment and hence various orthodontic appliances have been utilized to achieve that. To mention a few, there are functional/orthopedic appliances such as cervical pull / J-hook headgears, bionator, activator, anterior bite plane, etc. Other orthodontic protocols would be intrusion arches, reverse curve of spee wires, anchor bends, etc.

In 1980 Engel et al summarized four orthodontic approaches for deep bite treatment including premolars extrusion to level the curve of spee in the lower arch, secondly intrusion and or proclination of the incisors; and lastly molars extrusion. He stated that during orthodontic treatment of deep overbite cases, growth could be advantageous if controlled properly. In certain orthodontic mechanics if not all, overbite correction probably occurs from a combination of molar extrusion, incisor

intrusion, labial flaring and jaw rotation.

When deep overbite treatment is targeted in teenagers, facial growth as well as several other factors as incisors display and lower facial height have to be taken into consideration compared to non-growing adults with no vertical ramal growth. Extrusion of posterior and middle buccal segments is always a treatment of choice in growing patients with reduced lower facial third. Since during normal growth, the vertical distance between maxilla and mandible tends to increase, it is useful to count on it while opening an excessive overbite in growing patients. As it is widely accepted that correction of deep bite is both easier to accomplish and more stable when it is performed on growing patients than when it is attempted on those with no appreciable growth remaining.

Since their introduction into orthodontic practice in the 1880's, bite plates have been used as an adjunct in treatment of excessive anterior overbite. Different experienced orthodontists have primarily used them to help open the bite but no consensus has been reached regarding its mechanics. A sharp variance of opinion exists concerning the bite plate's induced changes; one school of thought developed by Mershon (1937) insists that it mainly causes depression or intrusion of lower anterior teeth with no eruption effect on the posterior dentition. Another view as expressed by Hemley (1938) among others totally believed that it's only elevation of molars and premolars that occur during orthodontic treatment using bite plates.

A quantitative analytic study done by Belger in 1956 using cephalometric radiographs of a total of 47 subjects was conducted to evaluate the physiologic vertical growth. Three categorized groups were included in the study, 25 controls, 12 treated with bite plates only and third group of only 10 subjects treated with bite plates together with other orthodontic appliances. He concluded that height increase due to growth only was predominantly at the mandibular molars and premolar region more than their maxillary counterpart. The bite plate sample had more height increase in the upper premolars and lower first molars, he explained the lack of maxillary molars eruption due to the bite plate's clasp. The third group showed more eruption of the mandibular dentition than their maxillary counterpart due to the extrusive nature of fixed orthodontic appliances forces.

Only a few studies have measured the contributions of tipping and bodily movements, which occur some orthodontic techniques, while controlling for normal growth. However, there have been no studies that examined the dento-alveolar and skeletal effects of anterior bite elevators either clinically or radiographically. The aim of our study is to retrospectively examine cephalometric radiographs, and perform superimpositions to identify the relative contributions of tipping, bodily movement, intrusion of anterior teeth, and extrusion of posterior teeth in resolving deep bites, when treated with anterior bite elevators concurrently with fixed edgewise appliance while matching for growth with untreated controls.

MATERIAL AND METHODS

Subjects

This longitudinal retrospective study was conducted following the protocol established and approved by the Institutional Review Board of Case Western Reserve University (IRB #2017-2179). Lateral cephalograms of 57 consecutively treated patients were collected from a single private orthodontic practice (Marissa Keesler, Neenah, WI). All patients were treated with 3 or 5 mm long anterior bite elevators (bite turbos) fixed behind their upper central incisors. Elevators were used concurrently with .022 x.028" self-ligating brackets (Roth prescription) and for Angle class II malocclusion subjects, short double elastics were used for no more than 3mm correction. Pre- and post-treatment lateral cephalograms were routinely taken in the office as a part of diagnosis and treatment planning as well as to assure that all treatment objectives were achieved and as a part of the after treatment documentation.

After examining treated subjects' radiographs, photographs and treatment charts; only 30 sets of lateral cephalograms met the inclusion criteria and were included in this study. The inclusion criteria were: (1) Orthodontic treatment using anterior bite elevators, (2) Deep anterior overbite prior to treatment (≥5 mm), (3) Growing adolescents age 10-14 before starting treatment, (4) Angle class I or II malocclusion with complete permanent dentitions except third molars, (5) Positive anterior/posterior overjet. Excluded subjects had at least one of the following criteria: (1)

Non-growing or Angle class III malocclusion patients, (2) Subjects who underwent extractions or have congenitally missing permanent teeth (except third molars), (3) Use of any functional orthopedic appliances (e.g. Headgear, bionator, herbst, etc.) or Class II correctors (forsus, jasper jumper, etc..), (4) Utilization of intrusion arch mechanics or reverse curve of spee (R.C.S.) wires or temporary anchorage devices, (5) Subjects treated with craniofacial disorders or treated with orthognathic surgery, (6) Inadequate diagnostic quality of radiographs.

A control group of 30 subjects matched on age, gender and Angle malocclusion was obtained from the Bolton Brush Growth Study Center (Cleveland, Ohio).

For 80% power and an alpha level of 0.05, means difference was .3633 and standard deviations difference was .3440 for mandibular skeletal change (MNSK). Both were calculated to be 28 subjects for each group as our sample size.

Image Collection

All treatment radiographs were taken on a single machine (CS 8100SC, Carestream Dental LLC, Atlanta, GA, USA) with patients in natural head position and maximum intercuspation. The magnification of the lateral cephalograms was consistent at 8% and all images were de-identified prior to digitization by the investigator (S.E.). Control group lateral cephalograms were retrieved from the digital library of the Bolton Brush legacy collection after being scanned via film digitizer (VIDAR

DosimetryPRO advantage, systems corporation, Herndon, VA, USA). All orientations and measurements were performed by same investigator.

Technical details

All images were digitally traced by one investigator (S.E.) using commercially available imaging software (Dolphin version 11.95, Patterson Dental Supply INC., St. Paul, MN). Image calibration of the treated sample was executed using the x-ray machine fixed calibration 30 mm ruler to eliminate any magnification errors. For the control group, permanent marks were placed on the radiographic films prior to digital scanning for calibration, a consistent distance of 178 mm between those marks was achieved using a template.

If showing on radiograph, bilateral anatomical structures were traced by bisecting both to average the measurements to the true mid-sagittal value and reduce error. Thorough comprehensive cephalometric tracings were performed on all 60 radiographs to ensure proper evaluation of skeletal and dental anatomical changes from T1 to T2 in each group. To properly evaluate bodily versus tipping movement of incisors, the center of resistance (CRes) of incisors was estimated at one third of the root length from the apex to the CEJ. Due to the possibility of root resorption during treatment the time one upper and lower central incisors were used as a template for all subsequent measurements that used CRes.

By default, Dolphin imaging software doesn't have CRes of incisors as a traceable landmark so; this landmark was added as a custom

landmark for this analysis. As previously stated the T1 incisor form and size was used to transfer the center of resistance from T1 and T2 to ensure that apical root resorption didn't introduce any methodological error during superimposition assessment.

According to Kishyama (1987) and Parker (1990) who both used a similar yet modified analysis, cranial base superimposition allowed accurate vertical evaluation for treatment effects. Pre- and post-treatment lateral cephalograms were superimposed on the cranial base using Dolphin imaging software with a best fit on the greater wing of sphenoid, planum sphenoidale and the anterior wall of sella. This cranial base superimposition method is regarded the most accurate since the registered landmarks are considered extremely stable and unchanged in shape or size over time after the age of 7 (Melsen, 1974).

This is in contrast with Kishiyama (1987) who used Pterygoid-Orbitale +3 line as registration line for superimposition as it represents the path of maxillary nerve and approximately parallels the palatal development during growth (Enlow 1982, Moss 1967). And different from Parker (1990) who used cranial base superimposition to transfer Pt-Or+3 line from T1 toT2 from vertical measurements.

A digitally modified version was developed based on the analysis developed by Kishiyama in 1987 followed by Parker who slightly modified the original vertical analysis in 1990. This analysis was inspired by Lysle Johnston's pitch fork analysis that has proven to be a valid tool to assess different orthodontic treatment effects skeletally and dentally. With the

advances of digital imaging software that enabled us to accurately digitize and superimpose our radiographic images followed by using Kishiyama's modified analysis, we were able to assess all components of teeth movement and skeletal changes due to treatment and growth individually.

In this study method, no fiducial lines were needed as all measurements are accurately calculated digitally to the tenth of millimeter along the Y-axis after 2-D cranial base superimposition, which eliminates additional technical steps that might contribute for more error and measurement inaccuracies.

Variables/Measurements

Skeletal and dental measurements were calculated as proposed by Kishiyama et al (1987) and later on modified by Parker et al (1990), which resulted in total of nine variables (7 linear measurements in mm and 2 angular in degrees). All numbers were rounded to the nearest tenth digitally via Dolphin imaging software, which yielded higher accuracy compared to manual tracing measurements due to reduction of human error.

The following abbreviations were used for the seven variables used in the anterior vertical analysis: (1) MXSK: Maxillary skeletal change which represents the vertical change of ANS from T1 to T2, (2) BUI: Bodily movement of maxillary incisor representing amount of extrusion or intrusion of U1 calculated by subtracting U1 CRes from ANS, (3) TUI:

Tipping of maxillary incisor, which assess vertical overbite changes due to U1's long axis angular changes and it is evaluated by subtracting U1 tip from U1 CRes, (4) TLI: lower incisors tipping which is similarly calculated like tipping of upper incisors and its value is assessed by the difference between L1 tip and L1 CRes , (5) BLI: Bodily movement of lower incisor showing amount of intrusion or extrusion of lower incisors and it is evaluated by subtracting L1 CRes from Me, (6) OB: overbite changes (7) MNSK: is the mandibular skeletal change which is the distance between ANS and Me from initial to final and it depicts the vertical mandibular displacement changes as well as the amount of molar extrusion.

Two angular measurements were considered influential while evaluating deep overbite correction added to considering the mandibular shape changes during growth that might contribute to change in overbite more than the size of the mandible as suggested by Richardson (1969), Moss and Salentijn (1971). First was GA: gonial angle measured between inferior of the mandible and the postetior border of the ramus. MPA: mandibular plane angle measured between sella-nasion plane with the mandibular plane (constructed Gn to Me).

Signs designation

As shown in table #1, positive values were assigned to all skeletal and dental movements that contribute to any increase in the amount of vertical incisal overlap (towards the occlusal plane). A negative sign was

given to those responses associated with decrease in vertical overbite (away from the occlusal plane).

Statistical methods

All data analyses tests were performed in SPSS software programming (Statistical Package for the Social Sciences, SPSS, version 17.0, Chicago, IL, USA). Testing for normal distribution of each parameter was accomplished with a Shapiro-Wilks test. Descriptive statistics (means, standard deviations, and ranges) were calculated for gender, age and molar classification in matched treated and control.

All nine variables were delta values determined by subtracting the difference between T1 and T2 either for treated or control group. Testing for normal distribution of each parameter was accomplished with a Shapiro-Wilks test. Descriptive statistics (means, standard deviations, and ranges) were calculated to assess effectiveness of gender, race, and age matching as well as to determine the presences of dento-alveolar changes between the treated and control individuals. T-test was used to compare the differences and evaluate statistical significance between the means of both groups, was used on SPSS. For all tests, alpha was ≤ 0.05

To assess for investigator's tracing and measurement error, 10 random subjects, 5 of each group were retraced and superimposed then measured by same investigator for intra-rater reliability. All linear and angular variables were re-calculated fifteen days apart to test for intra-class correlation coefficient (ICC).

Results

As previously mentioned 30 treated subjects fulfilled our inclusion/exclusion criteria from a total of 57 patients recruited from a single private practice (M.K., Neenah, Wisconsin). The final sample had 15 male and 15 female, Caucasians. The mean age at starting treatment was 12 years, 02 months (± 2 months) and the mean age at debond was 14 years, 7 months (± 7 months). Mean duration of treatment using the anterior bite elevators was 12 months (± 4 months) of average total treatment duration of 2 years, 4 months (± 6 months). Two thirds of the patients were Angle class II and one third were Angle class I.

The control group was selected from the Bolton Brush Growth Study matched on age, gender, race and Angle classification. Gender and molar classification were perfectly matched to the treated group. However, the range of age varied slightly in the control group at T1 with a mean of 12 years, 7 months (± 5 months) and at T2 the mean age was 15 years, 2 months (± 6 months). Mean time interval in controls was 2 years, 6months (± 5 months). Descriptive statistics including means and standard deviations of the treated and control groups are listed for reference (table #2).

For comparative purposes of this study, all variables at T1 for the treated and control groups were measured to ensure comparable starting point for both even after matching for other factors. There were only two variables that had a significant difference between groups; OB in the

control group was 0.8 mm deeper than the treated group ($p \leq 0.001$). Also TUI had a higher mean in the treated group (22.8 mm) compared to control mean of 21.3 mm, which means that U1 were more upright in the treated group ($p \leq 0.001$). Besides OB and TUI, there were no other significant differences between the groups in the amount of vertical position of the upper and lower incisors in reference to ANS/Me, inclination of the lower incisors, the skeletal position of maxilla/mandible, gonial angle and mandibular plane angle (table #3).

During assessment for skeletal and dental changes post-treatment, six variables (MXSK, BUI, TUI, TLI, MNSK and MPA) met our parametric assumptions based on the Shapiro-Wilk test, independent paired t-tests were used to detect significant difference between those variables. While the remaining three (BLI, OB and GA) weren't normally distributed according to the same normality test, necessitating the use of the Mann-Whitney test.

Mean changes and standard deviations between T1 and T2 of all variables for both groups are shown in (table #4). The use of anterior bite elevators in conjunction with pre-adjusted edgewise appliances resulted in significant changes in all variables tested except MXSK and Go when comparing the treated group to the control sample.

Maxillary skeletal change (MXSK) was not statistically significant between groups ($p \geq 0.05$) although treated subjects showed mean of 2.3 mm (± 0.9) downward growth compared to the control sample, which

showed slightly less vertical change 2.4 mm (SD ± 0.7). While MNSK was statistically significant (p≤0.001) with a treated group mean of -6.0 mm (± 1) compared to -4.3 mm (± 0.9) in the controls (figure #1). This represents a 71.6% increase in Menton to ANS for the treated group.

Maxillary incisor variables showed significance in bodily movement (BUI) and tipping (TUI), (p≤0.001). Mean extrusion was 1 mm (± 0.3) in the treated group compared to 1.6 mm (± 0.4) in the controls. Thus there was 62.5% reduction in bodily movement of the upper incisor towards the occlusal plane in the treated sample. There was also a significant difference in tipping (p≤0.001) with a mean of -0.6 mm (± 0.4) in the treated sample compared to 0.3 mm (± 0.3) which is probably explained by torque applied with edge-wise appliance that resulted in 30.7% more U1 tipping away from the occlusal plane in treated patients.

Regarding mandibular incisor movements, the following was observed: Extrusion mean (BLI) was 1.4 mm (± 0.6) compared to control of 2.5 mm (± 0.8). This can be explained as 56% less extrusion of lower incisor was achieved in the treated group in contrast with controls where the lower incisor kept moving to the occlusal plane due to lack of anterior coupling (p≤0.001). Tipping mean (TLI) was -1 mm (± 0.6), which gained negative value as the lower incisor tip moved away from the occlusal plane by 43.4% more than in the control sample (p<0.001), which has mean of 0.3 mm (± 0.2). Dental tipping and bodily movement values are illustrated in figures #2,3.

Subsequently and due to changes in all discussed variables, OB was decreased significantly ($p \leq 0.001$) in treated group, which had a mean of -5.2 mm (± 0.7) as opposed to control mean of 0.4 mm (± 0.9) as shown in figure #5.

Angular variable GO showed no significance difference between the two groups after running Mann-Whitney test ($P \geq 0.05$) while MPA showed significant difference ($p \leq 0.001$) between treated and control samples with a mean of 1.9 degrees (± 0.9) and -0.8 degrees (± 0.7) respectively (figure #4)

To assess tracing and measurement error, 10 subjects were randomly selected (5 of each group) and were retraced, measured followed by superimposition. All linear and angular variables were calculated for the nine variables to test for intra-rater reliability. Values of intra-class correlation coefficient ranged between 0.908 and 0.958 with a mean of 0.933, which shows excellent repeatability of tracings and measurements.

Discussion

Anterior bite elevators or also known as anterior bite turbos are a relatively new tool in our orthodontic armamentarium. They offer a better alternative to conventional bite plates considering their size and ease of use with no need for laboratory work involvement. And as they are being used in conjunction with edgewise appliances, we were interested to examine the dento-alveolar changes during orthodontic treatment. We aimed at quantitative evaluation of the relative contributions of skeletal and dental components during the correction of deep anterior overbite in growing adolescents.

The results revealed that overbite correction was predominantly achieved by increasing lower anterior facial height (MNSK) due to allowance of eruption of posterior segments. This was in agreement with what Bahador and Higley found in their study (1944), although they believed that more cases displayed that maxillary teeth showed more eruption than opposing mandibular dentition, an assertion which was not assessed in this study.

Our sample consisted of 30 subjects who fulfilled the study's inclusion/exclusion criteria; all treated by the same orthodontist who utilized anterior bite elevators in conjunction with 0.022" pre-adjusted edgewise appliances for deep overbite correction. In his PDS user's manual (2015), Roncone mentioned that to allow for apical bony fill of posterior dentition after eruption, anterior bite elevators as known as bite

turbos have to kept in place for at least 8 to 9 months and in our sample the average was 12 months to eliminate relapse of overbite.

Relative and absolute intrusion of the lower incisors were the second and third biggest contributors to deep overbite reduction while the relative and absolute intrusion of upper incisors were the least. This was in contrast with Hemley in 1939 where he believed that bite plate only stabilized the vertical height of lower incisors compared to growing controls and even the few cases where lower incisors were depressed, he described it to be a temporary phenomenon.

As our natural growth is a contributing factor for overbite changes, it had to be factored out from the equation so; we can precisely assess the pure effect of orthodontic treatment with anterior bite elevator mechanics. The use of matched control group gave us this opportunity to adjust the results for changes that would have normally occurred with growth alone. Isolating the effects of orthodontic treatment from other growth changes is extremely important and crucial so, we can understand exactly what are the dynamics of overbite correction that happened solely due to treatment.

When we evaluated at lower vertical facial height change (MNSK), we found that even though maxillary growth (MXSK) moved ANS towards the occlusal plane by an average of 2.3 mm, which might contribute for deepening the bite. Yet MNSK moved vertically 6 mm away from the occlusal plane with a high contribution in overbite reduction in the treated group (figures #6,8). This was in contrast with Damon as he found in 1995

that relative and absolute intrusion of incisors were the key of opening the bite while maintaining the mandibular plane angle and not the affecting the lower facial height. But we have to consider that his sample was treated with 4 premolars extraction using tweed mechanics.

Looking closely at skeletal changes at ANS (MXSK) and maxillary incisors. We found almost same vertical downward growth of maxilla with no significant difference detected as our measurements between groups resulted in only 0.1 mm difference ($P \geq 0.05$). On the other hand, U1 showed significant less bodily extrusion of 0.6 mm during treatment. As well as 0.9 mm more labial tipping of than the controls, which is probably due to edgewise torque expression. Those findings are in contrast with study done by Forsberg et al. (1984) where they interestingly found an anterior fixed bite plane resulted in anterior rotation of maxilla and retardation in vertical development of the upper face height.

Anterior bite elevators were fixed behind the upper central incisors since the beginning of orthodontic treatment while leveling and aligning as proposed by Roncone (2015). One might think that utilizing those elevators might hold upper and lower incisors stationary while leveling and aligning remaining dentition but we believe that in our sample extrusion of upper and lower incisors still occurred although to a lesser extent than controls despite the extrusive nature of most orthodontic mechanics.

With the advances of digital imaging softwares that enabled us to accurately digitize and superimpose our radiographic images guided by

using Kishiyama's modified analysis, we were able to assess all components of teeth movement and skeletal changes due to treatment and growth individually. Figures (7,8) are showing the variables contributing to the overbite change; arrows and numeric values indicate the direction and the quantity of changes in each variable. As mentioned in the study methodology, all movements that were towards the occlusal plane were assigned positive value and the opposite for negative values.

The control group showed slight deepening in the overbite by only 0.4 mm from T1 to T2. This was important to put into consideration when evaluating the treated growing adolescents, as we had to determine the relative contribution of normal growth on overbite change in our matched controls. And as mentioned by many researchers, there is no consensus on overbite changes either positive or negative in growing teenagers but they agreed on its subtleness unless orthodontic intervention (Baume 1950, Bjork 1953, Moorees 1959, Herness 1973 and Moyers 1976).

Various facial types have been extensively examined in our literature and since then it has been widely believed that facial types have a strong relationship with dental overbite and hence require different treatment approaches. Wylie (1946), Schudy (1964) and Creekmore (1967) have all agreed that different facial types will respond differently and how to tackle it during orthodontic treatment. In this study our treated sample were all categorized as having an average lower facial height of 62 mm that coincides with the norms (64 mm ±4) and a mandibular plane

angle average recorded at 32.9 degrees. Both values suggest that our treated group as well as the matched control are normodivergent with normal facial growth patterns of which helped us to control any confounding factors related to facial types.

Upon having a closer look, general orthodontic mechanics have extrusive nature, which by itself can be participating factor in overbite reduction. But keeping in mind that it happens in both anterior and posterior segment, it shouldn't affect by either deepening or reducing the overbite significantly. Same for class II elastics; which were the only tool used for correction of the class II malocclusion patients in our sample. As they cause mandibular posterior eruption, anterior maxillary segment will extrude as well, ending up with same overbite amount.

Our findings in this study showed that the treated group had 6 mm increase in lower facial height during treatment duration of an average 29 months while 1.7 mm annual increase in MNSK for the untreated control group, which is slightly different that what McNamara has reported in 1981. He believed that lower facial height typically increase 1 mm per year in untreated individuals and this is proportionate with the molar height increase to compensate and to keep posterior dentition in occlusion.

All functional appliances like headgear, twinblock or bionator are believed to affect the maxillary complex by holding the vertical while allowing the downward and forwards mandibular growth to be more pronounced. It was an interesting question to be answered in the study to

check for anterior bite elevator mechanics effects on skeletal maxilla and unsurprisingly, there was no significance in MXSK mean as the difference was only 0.1 mm between both groups.

In our humble opinion, anterior bite elevator mechanics should be considered in normal low facial height patients with excessive anterior overbite. They would benefit the most especially if they possess a good chin projection as during increasing mandibular plane angle and rotating the mandible downward and backward, chin point might move dorsal. Lower facial height (MNSK) increase noticed on most of our sample of a net 1.7 mm after factoring out growth (figure 9).

Conclusion

Deep overbite correction was achieved efficiently using anterior bite elevators in conjunction with edge wise appliance compared to matching control group. Significant bodily and tipping movements of upper and lower incisors (69%) contributed to overbite reduction although the most significant contributor was increasing lower facial height (31%) while allowing posterior segment eruption.

Limitations

This study has the following limitations, first and foremost is the inability to three dimensionally evaluate the dento-alveolar effects of anterior bite elevators effects due to availability of 2D radiographs only. Second was not identifying if increase of lower facial height was due to eruption of maxillary or mandibular posterior segments. Lastly is limited sample size with regards to class I versus class II malocclusion to check for inter-group significant difference.

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NOTICE OF APPROVAL

CWRU IRB Protocol Number:	**IRB-2017-2179**
Protocol Title:	***The Cephalometric Effects of Utilizing Anterior Bite Elevators in Treatment of Deep Bites***
Responsible Investigator (RI):	**Mark Hans**
Co-Investigator (CI):	**Manish Valiathan, Sherif Elbarnashawy**
RI Department:	**Case Western Reserve University IBC and SBER IRB - DEN - Orthodontics**
Type of Review:	**Expedited**
Risk Level:	**Minimal**
Vulnerable Population(s):	**None**
Approval Date:	**04/12/2018**
CONTINUING REVIEW DEADLINE:	**03/11/2019**
EXPIRATION DATE:	**04/11/2019**

The CWRU Institutional Review Board (IRB) has approved the above new protocol through the **EXPEDITED** review process.

When conducting Human Subjects' Research, your responsibilities include the following:

1. Report all adverse events and unanticipated problems involving human subjects to the IRB Office, located in the Office of Research Administration (ORA), within three (3) business days of your knowledge of the occurrence.
2. Provide the IRB with a complete Continuing Review form (available in our electronic application system at http://sberirb-app.case.edu, or from the ORA) by the continuing review deadline noted above, and when the study is to be terminated.
3. Submit all proposed changes to the protocol to the IRB and wait for IRB approval before implementing any protocol change or modification.
4. Keep all research data and original consent documents in your possession for at least three (3) years after the study is terminated.
5. Note that completely de-identified data can be kept and used for research indefinitely. The IRB is primarily concerned about identifiers/identifiable data. If you want to terminate your study, identifiers/identifiable data must be destroyed. This includes paper or electronic master lists, contact lists, codes/codebooks, transcripts containing identifiers and video and audio recordings.
6. If applicable, please use the most current IRB-approved consent forms. Feel free to use copies of these forms as long as they are identical to what was originally IRB approved. If you wish to change the forms or any other part of the study, you must submit an addendum request/protocol modification with revised copy(ies) of the relevant document(s) and wait for IRB approval before a modification can be implemented.
7. ***Discontinue all work pertaining to this protocol if a continuing review approval is NOT finalized by the expiration date noted above***. No further work on this protocol is allowable until the proper continuing review materials or required revisions are approved by the IRB.

    a. Please note that, if the continuing review materials or required revisions are not received by the expiration date, the RI and this study would be automatically placed on Administrative Hold for 30 days. This means that the RI loses their IRB privileges and research from this study must cease.
    b. If after 30 days, the CWRU IRB still does not have the protocol for processing, this protocol will be administratively terminated and your IRB privileges will be revoked for all your protocols.

Thank you for your attention to this matter. Please contact the IRB office at 216-368-6925 if we can be of further assistance.

IRB Administration Offices
UH IRB Phone: 216.844.1529
CWRU IRB Phone: 216.368.6925

APPROVAL

Principal Investigator:	Mark Hans
Title:	The Cephalometric Effects of Utilizing Anterior Bite Elevators in Treatment of Deep Bites
IRB Number:	IRB-2017-2179
Submission Number:	CR00001509
IRB Office:	CWRU IRB
Approval Date:	4/10/2019
Effective Date:	4/10/2019
Expiration Date:	4/9/2022
Type of Submission:	Continuing Review
Type of Review:	Expedited
Documents Reviewed:	• 2017-2179 iris.pdf, Category: Other;

The IRB reviewed this submission.

- Per Federal regulation, changes MAY NOT be made to any element of the current research without prior IRB approval, except to eliminate an immediate and apparent hazard to subjects enrolled in the study.
- Per Federal regulation, the research may not continue beyond the Approval End date. You must submit a continuing review form 6-8 weeks before this Approval End date in order to maintain IRB approval. Failure to maintain IRB approval is human subjects non-compliance. Please note that even if your study falls into a category that does not require an Approval End date, the institution may require a yearly "check-in" to confirm the status of the study.

***Approval by the IRB does NOT mean that you have permission to start your study. Prior to starting your study, you may be required to obtain (1) a coverage analysis for studies that involve patient care, regardless of source of funding, and/or (2) a contract with the Sponsor of your study or an agreement with any third-party collaborator that may receive UH or CWRU patient information in any format. Please ensure that all required approvals are obtained before initiation of research activity. ***

The UH IRB operates under HHS Federalwide Assurance (FWA) number 00003937 and IRB registration numbers 00000684, 00001691 and 00008600. The CWRU IRB operates under DHHS FWA00004428 and IRB registration number 00000683.

Table #1: Convention of measurement signs

Sign / Variable	Positive (+)	Negative (-)
MXSK	Downward movement of anterior maxilla	Upward movement of anterior maxilla
BUI	Upper incisor extrusion	Upper incisor intrusion
TUI	Upper incisor uprighting	Upper incisor labial tipping
TLI	Lower incisor uprighting	Lower incisor labial tipping
BLI	Lower incisor extrusion	Lower incisor intrusion
MNSK	Upward movement of anterior mandible	Downward movement of anterior mandible
OB	Overbite increased	Overbite decreased
GA	Gonial angle became more obtuse	Gonial angle became more acute
MPA	Mandibular plane angle became more open	Mandibular plane angle became more closed

Table #2: Descriptive summaries of treated and matched control groups

	Treated	Control
Total sample	30	30
Females	15	15
Males	15	15
Angle class I	11	11
Angle class II	19	19
Mean age T1	12y 2m ± 0y 4m	12y 7m ± 0y 5m
Mean age T2	14y 7m ± 0y 7m	15y 2m ± 0y 6m
Time interval	2y 4m ± 6m	2y 6m ± 5m

Table #3: Comparison between treated and control groups at T1

	TREATED		CONTROL			
VARIABLE	MEAN	STD	MEAN	STD	P- VALUE	SIG.
MXSK	24.3	±3.2	25.1	±4.1	.170	NS
BUI	11.3	±1.3	10.7	±1.9	.061	NS
TUI	22.8	±2.4	21.3	±2.8	.000	***
TLI	15.1	±1.6	14.7	±2.6	.140	NS
BLI	23.6	±2.2	23.1	±2.8	.170	NS
MNSK	62.1	±3.6	61.2	±4.5	.108	NS
OB	6.2	±0.9	7	±1.4	.000	***
GA	123.3	±4.6	122.7	±5.1	.516	NS
MPA	32.9	±2.2	33.6	±2.5	.108	NS

* Significant p< 0.05 ** Significant p< 0.01 *** Significant p< 0.001

Table #4: Comparison of changes from T1 to T2 for treated and control groups

	TREATED		CONTROL			
VARIABLE	MEAN	STD	MEAN	STD	P- VALUE	SIG.
MXSK	+2.3	±0.9	+2.4	±0.7	.648	NS
BUI	+1.0	±0.3	+1.6	±0.4	.000	***
TUI	-0.6	±0.4	+0.3	±0.2	.000	***
TLI	-1.0	±0.6	+0.3	±0.2	.000	***
BLI	+1.4	±0.6	+2.5	±0.8	.000	***
MNSK	-6.0	±1.0	-4.3	±0.9	.000	***
OB	-5.2	±0.7	+0.4	±0.9	.000	***
GA	-1.0	±1.0	-1.2	±0.6	.601	NS
MPA	+1.9	±0.9	-0.8	±0.7	.000	***

* Significant p< 0.05 ** Significant p< 0.01 *** Significant p< 0.001

Figure #1: Mean Skeletal Changes

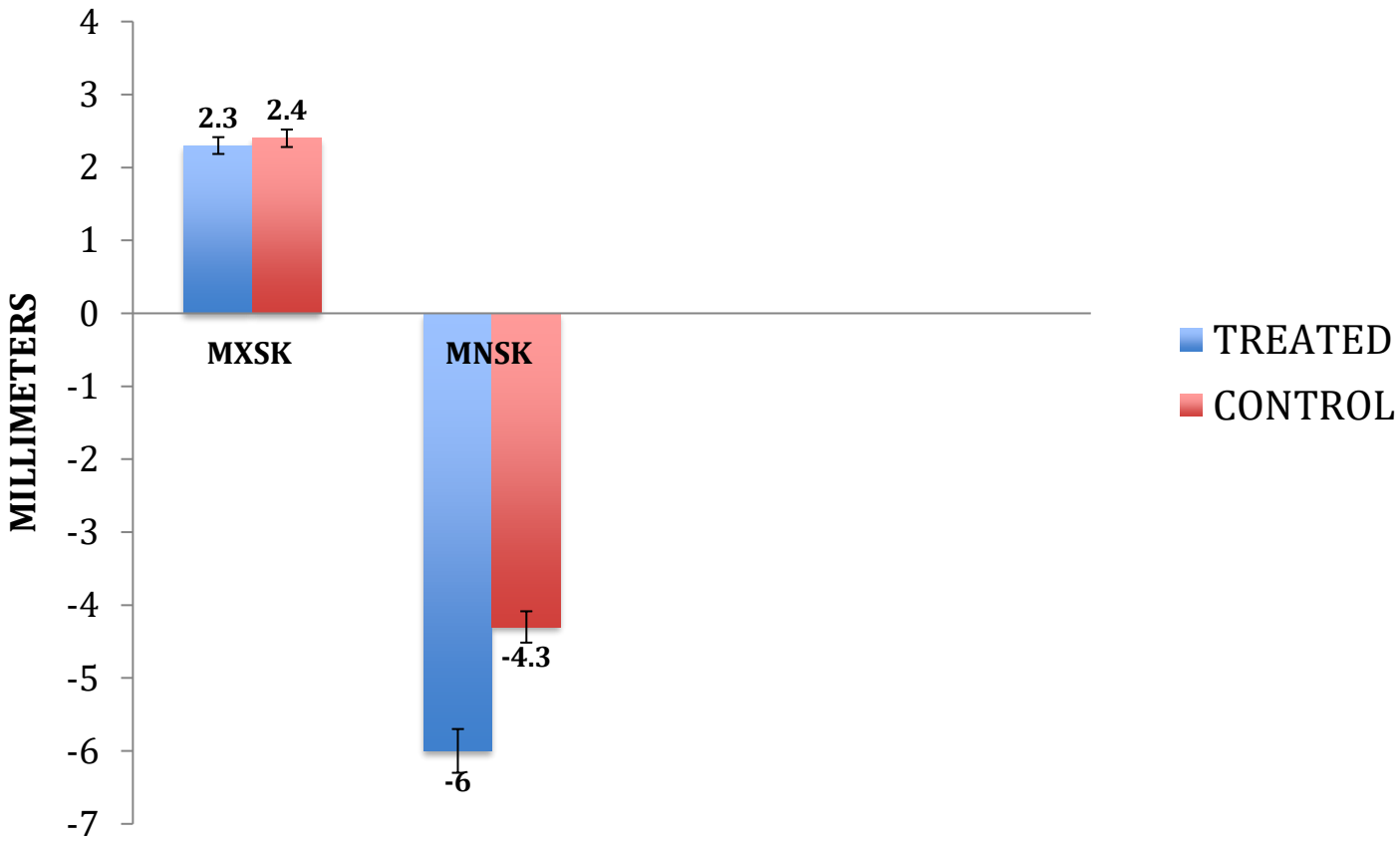


Figure #2: Mean Dental Changes (Bodily Movements)

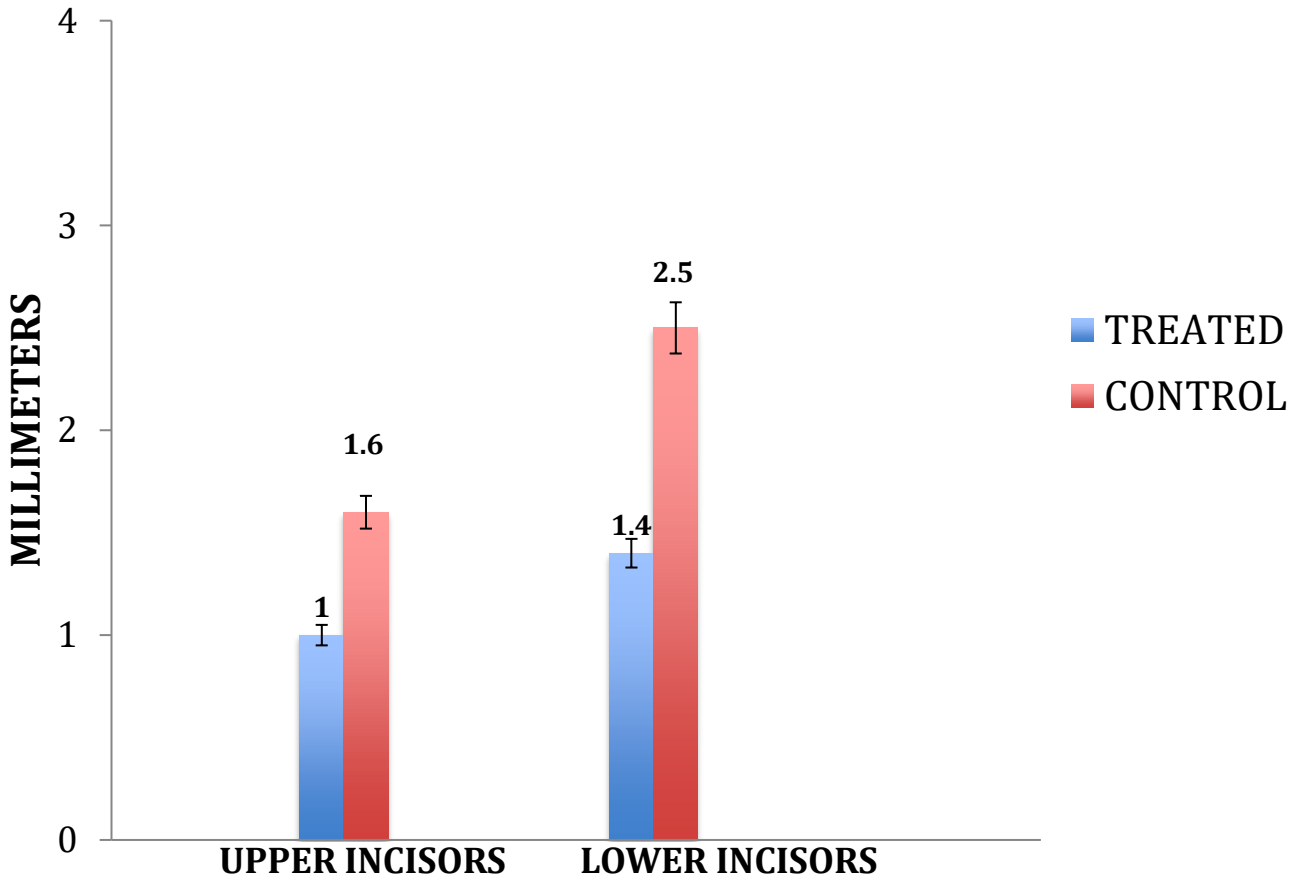


Figure #3: Mean Dental Changes (Tipping Movements)

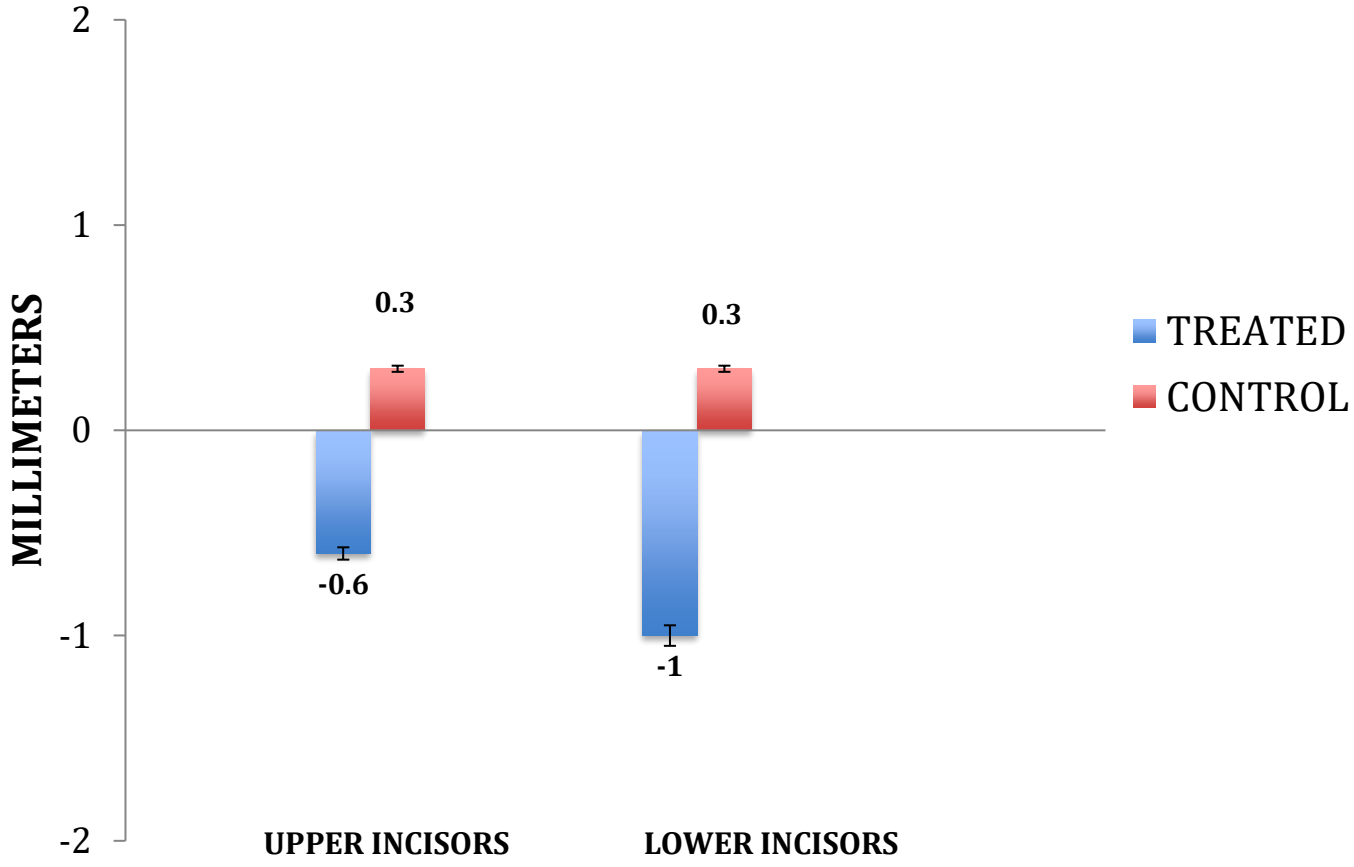


Figure #4: Mean Angular Changes

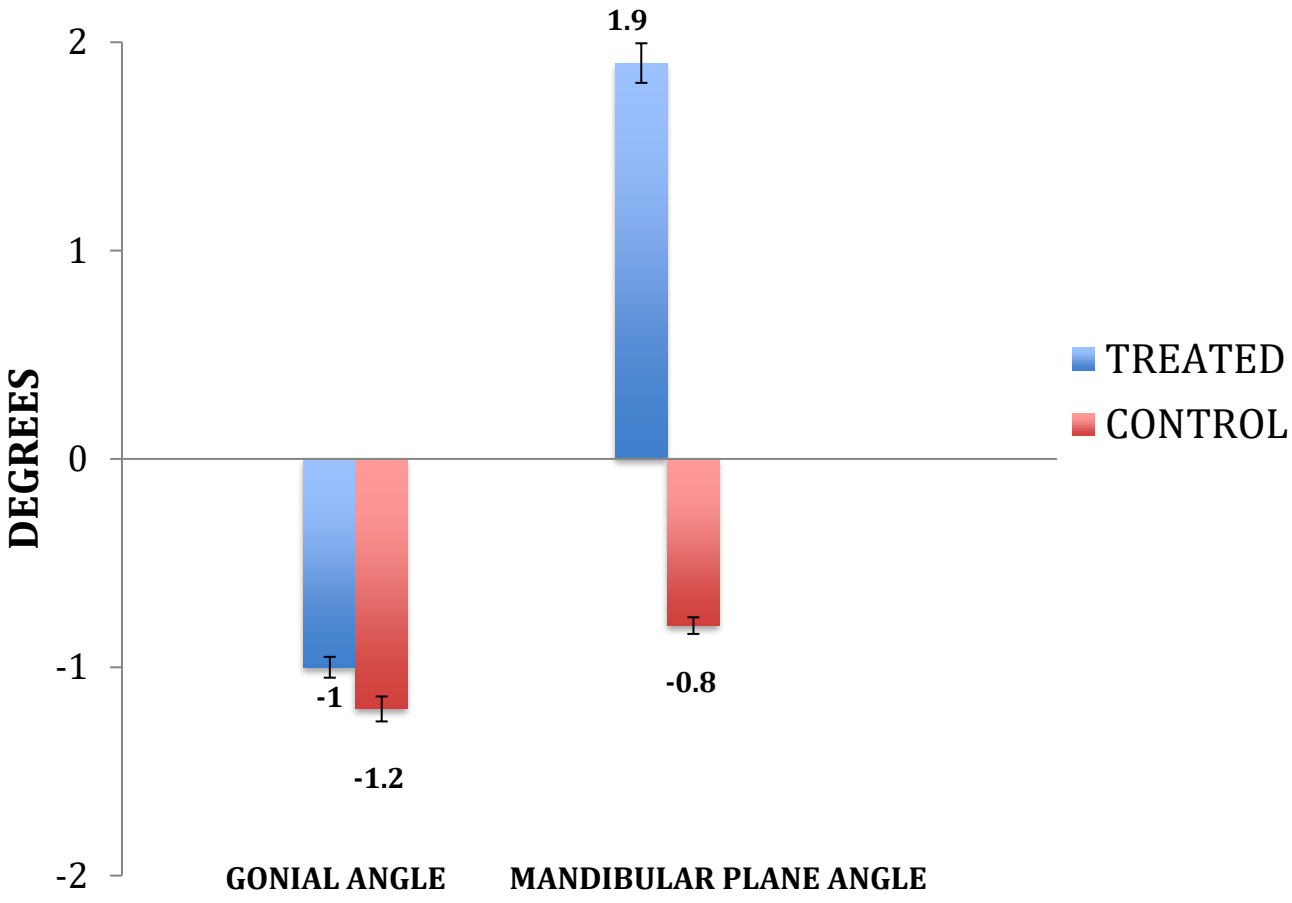


Figure #5: Mean Change in Overbite

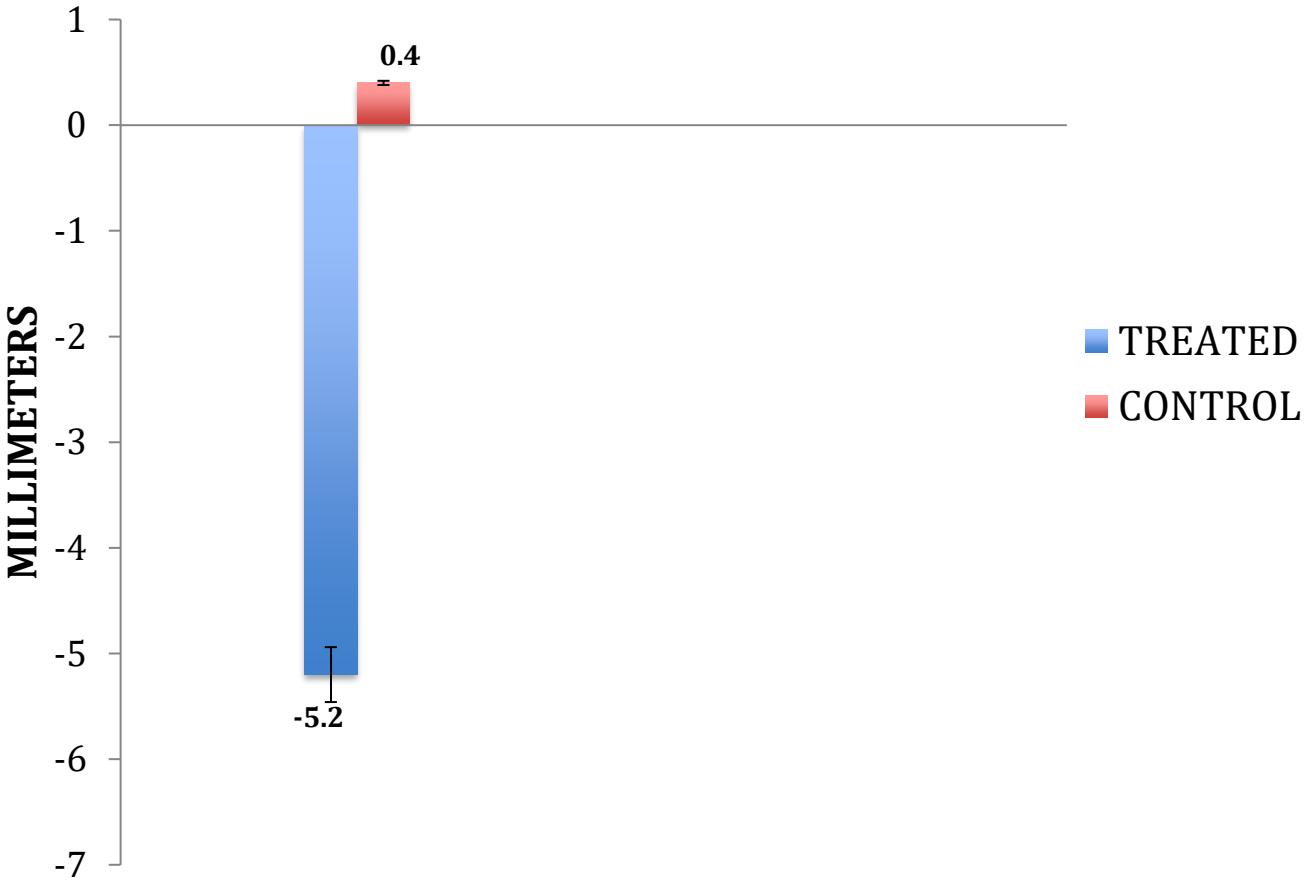


Figure #6: Net Contribution of Variables for Deep Bite Correction

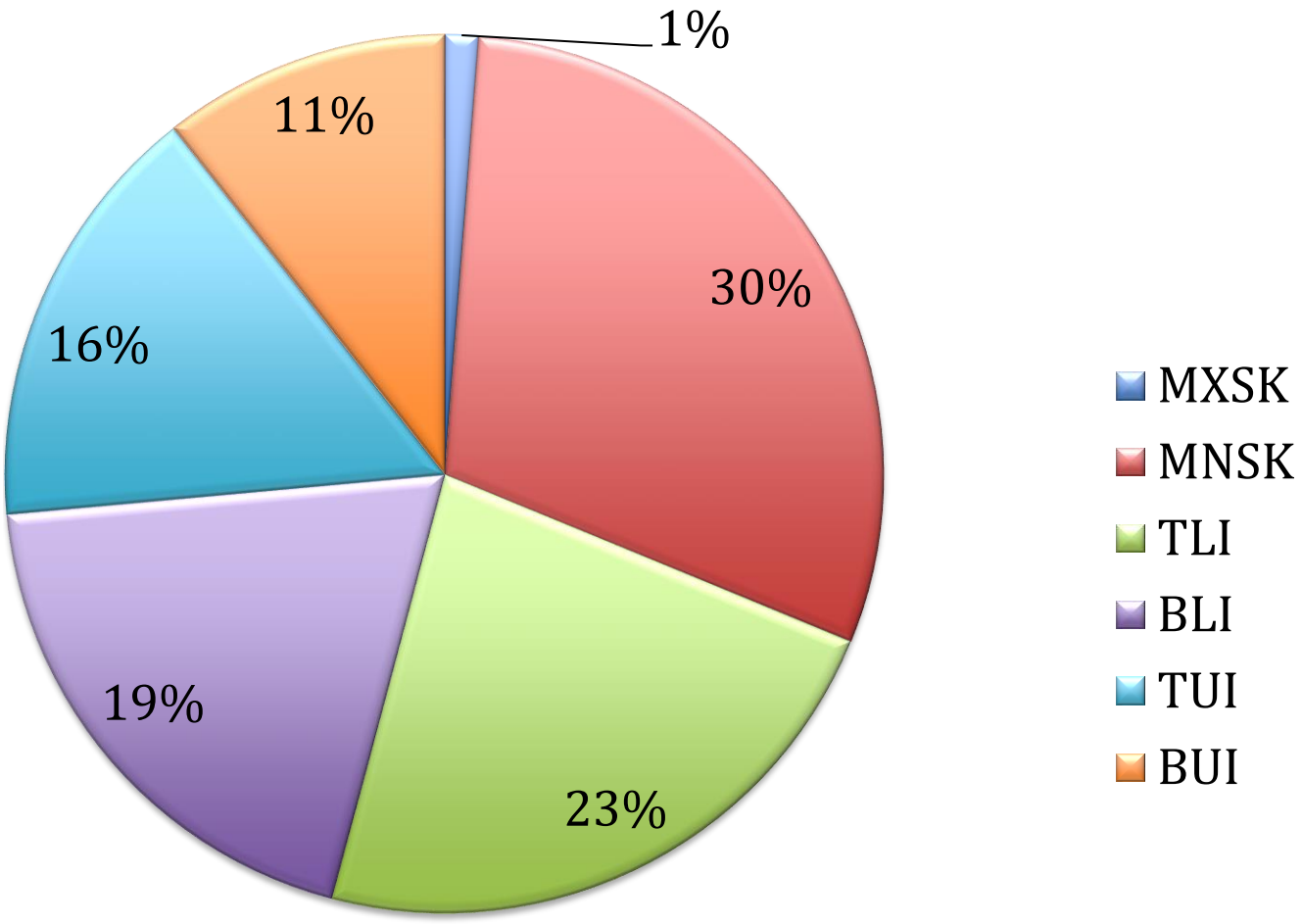


Figure #7: Schematic diagram illustrating dento-alveolar changes in control group

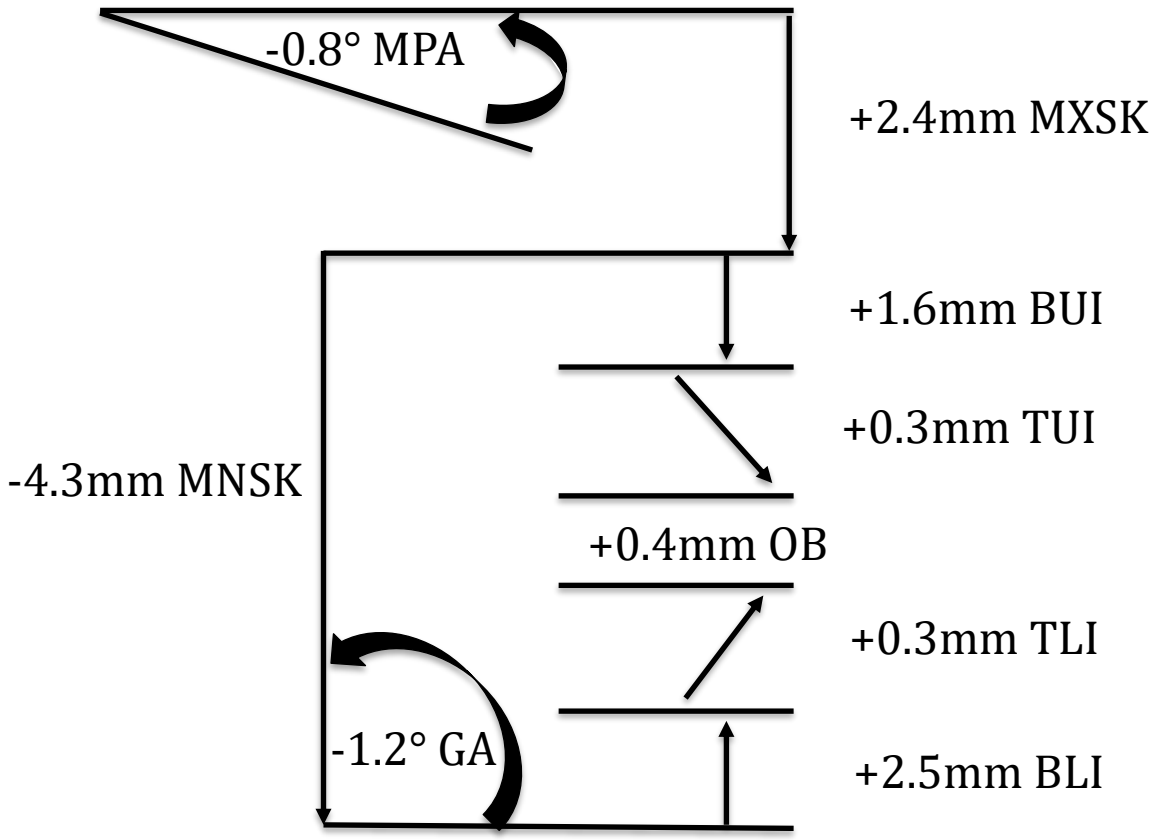


Figure #8: Schematic diagram illustrating dento-alveolar changes in treated group

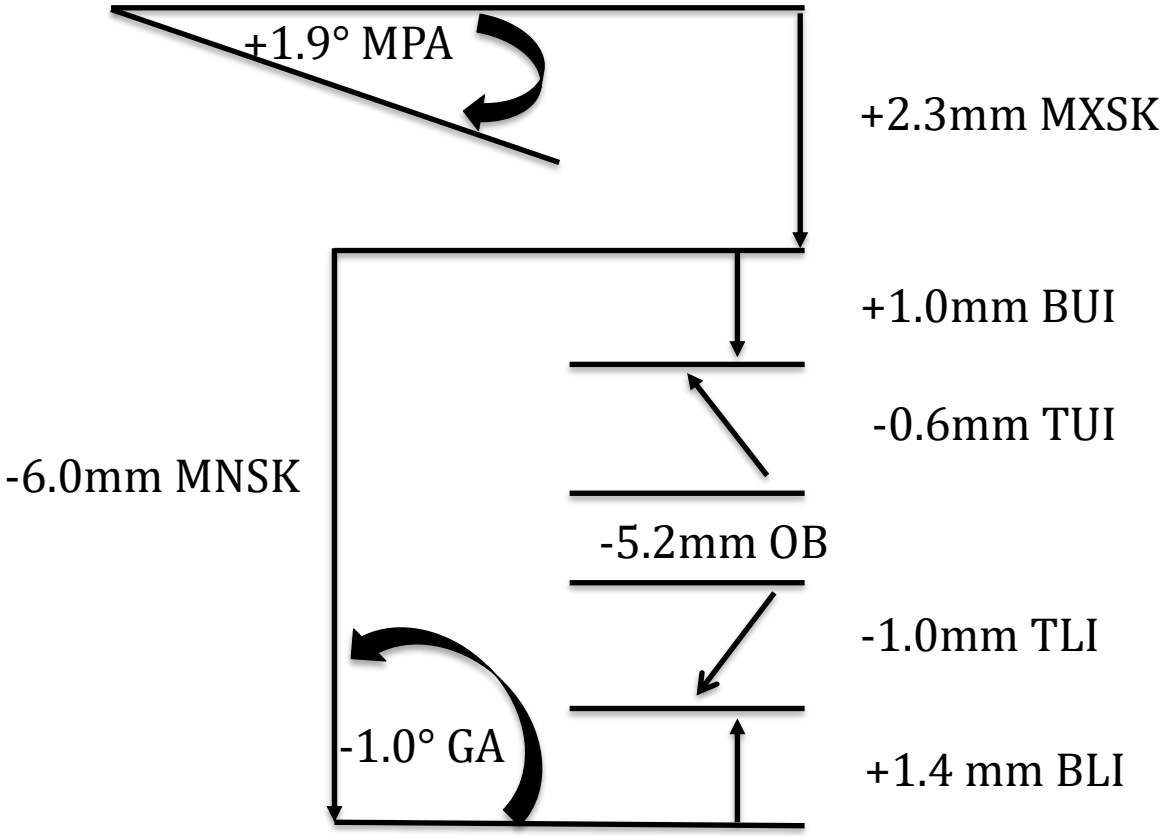


Figure #9: Schematic diagram illustrating net dento-alveolar changes (Treated minus control)

