CEPHALOMETRIC EVALUATION OF DEEP OVERBITE CORRECTION USING POSTERIOR BITE TURBOS IN COMPREHENSIVE ORTHODONTIC TREATMENT OF GROWING PATIENTS

by

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Submitted in partial fulfillment of the requirements for the degree of

Master of Science in Dentistry

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Graduation January 2025

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DEDICATION

I dedicate this thesis to my parents, whose sacrifices have blessed me to be in the position I am today. I am grateful to my sister, Min-Joo, for her unwavering support in all of life's endeavors. And to my husband, Matt - thank you for your patience and love through all the years of long distance; we will be reunited soon.

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ACKNOWLEDGEMENTS

To my thesis advisor, Dr. Mark Hans, thank you for your mentorship and guidance throughout the research process. To my thesis committee, Dr. Juan Martin Palomo and Dr. Ali Syed, I want to express my gratitude for your advice and expertise in your respective fields. A special thank you to Dr. Tarek ElShebiny, who though you were not a part of the committee, supported me in my research. And to my class – you guys are very special. Thank you for your friendship and camaraderie.

LIST OF ABBREVIATIONS

Anterior Nasal Spine (ANS): most anterior point of the bony projection of the maxilla

Center of Resistance (CR): point located at a distance of 33% of the root length, when measured from the alveolar crest

Maxillary Skeletal Change (MXSK): vertical distance between the location of the ANS at pretreatment and posttreatment

Bodily Movement of Maxillary Incisor (BUI): vertical distance between the ANS and CR of the upper incisor

Tipping Movement of Maxillary Incisor (TUI): vertical distance between CR and incisal edge of the upper incisor

Tipping Movement of Mandibular Incisor (TLI): vertical distance between CR and incisal edge of the lower incisor

Bodily Movement of Mandibular Incisor (BLI): vertical distance between the ANS and CR of the lower incisor

Mandibular Skeletal Change (MNSK): vertical distance between ANS and menton

Gonial Angle (GO): external angle of mandible, located by bisecting the angle formed by tangents to the posterior border of the ramus and the inferior border of the mandible

Sella-Nasion-Mandibular Plane Angle (MPA): angle formed by intersection of the sella to nasion plane and the mandibular plane

Overbite (OB): vertical distance between the incisal edge of the upper incisor and incisal edge of the lower incisor

Change in Overbite (∆OB): summation of changes in all variables (MXSK, BUI, TUI, TLI, BLI, MNSK)

Change in Anterior Facial Height (∆AFH): sum of the changes in MXSK and MNSK

ABSTRACT

OBJECTIVES: To evaluate the vertical outcomes of correcting deep overbite in growing patients using posterior bite turbos concurrently with preadjusted edgewise appliances.

MATERIALS AND METHODS: Thirty-four subjects were evaluated at pretreatment (T1) and posttreatment (T2) and compared to an untreated control group from the Bolton Brush Growth Study Collection (CWRU, Cleveland, Ohio). Subjects were matched based on age and sex. The Case Western Reserve University (CWRU) vertical cephalometric analysis was used to separate tipping movements of upper (TUI) and lower incisors (TLI), bodily movement of upper (BUI) and lower incisors (BLI), and anterior maxillary (MXSK) and mandibular skeletal changes (MNSK).

RESULTS: The overbite (OB) was reduced significantly in the treated group ($P \leq .001$) (2.2mm) compared to the control group. The change in the TUI ($P \leq .001$) (0.9 mm) was statistically significant. Much of the deep overbite was corrected through labial tipping of the upper incisors, followed by labial tipping of the lower incisors and maxillary skeletal control. Lower incisor intrusion and mandibular skeletal change also helped to reduce overbite. However, there was not a significant increase in anterior facial height.

CONCLUSIONS: Growing patients with deep overbite were treated efficiently using posterior bite turbos in conjunction with preadjusted edgewise appliances. Special consideration should be taken when treating individuals with reduced lower anterior facial height, as posterior bite turbos may effectively control the vertical maxillary and mandibular skeletal dimensions.

REVIEW OF LITERATURE

Overbite Epidemiology

Deep overbite has long been considered both a common and challenging form of malocclusion to treat.[1,2] Strang defined overbite as "the overlapping of the upper anterior teeth over the lowers in the vertical plane",[3] and this has widely and historically been expressed as a percentage value of the lower incisor length covered by the upper incisors.[4] Some have described the ideal incisor overbite as 20%, while others report a preference of 35-40%.[5] It is maintained that the amount of vertical overlap varies greatly,[6] and this variation was recorded in the third National Health and Nutrition Examination Survey from 1988 to 1991. According to the survey, the prevalence of a severe deep bite in the United States was found to be 8%.[7] The mean overbite in children ages 5-6 years old was 36.5 to 39.2%, while adults had an average range from 37.9 to 40.7%.[8,9,10]

Rather than a percentage, Williamson defined an ideal overbite as the incisal edge of the lower incisor resting on the cingulum of the upper incisor; a deeper bite resulting from the lower incisal edge resting beyond the upper cingulum.[11] Others have defined overbite through linear measurements, with average amounts of overlap ranging from 2.5 mm[12] to 3.1 mm.[13] When

measuring linearly, severe deep bites have been defined as having greater than or equal to 5 mm of incisor overlap, with 20% of children and 13% of adults experiencing this form of malocclusion. 95.2% of vertical occlusal issues have been attributed to severe deep bite.[14]

Etiologic Factors of Deep Overbite

The etiology of a deep overbite has been found to be multifactorial, with contributions from a range of dental, skeletal, and muscular components.[15] In regards to dentoalveolar morphology, some believe that the cusp heights of the posterior teeth have an effect on the amount of anterior overbite.[16,17] Others have found that there is a positive correlation between upper incisor height and overbite,[18] or lower incisor height and overbite.[19] It has also been proposed that there is a direct positive relationship between interincisal angle and overbite.[20,21,22]

While many have theorized throughout the history of orthodontics, there has been great support for the idea that a deep overbite is produced by a combination of infraeruption of the posterior teeth and supraeruption of the anterior teeth.[2,13,23,24] Proffit outlined this phenomenon of supraeruption of lower anterior teeth, especially in Class II, Division 1 retrognathic patients.[14] The

extent to which the anterior and posterior teeth erupt has also been associated with the individual's neuromuscular features.[23,25,26]

Proctor and DeVincenzo found that the orientation of the masseter muscle fibers was different for Frankfort, Sella-Nasion, palatal and mandibular planes in people with skeletal deep versus open bites. In subjects with skeletal deep bites, the masseter musculature was much more vertically placed, rather than horizontal.[27] The muscles of mastication have also been thought to exert varying levels of force in relation to the type of malocclusion. For deep bite patients, the force vectors are presumably applied in a more anterior and perpendicular fashion, causing molar infraeruption.[28] Another viewpoint asserts that in skeletal deep bites, the muscles are positioned normally while the capsule surrounding the muscle is irregular.[29]

In Class II, Division 2 patients, the etiology for deep bite has been correlated more with a shorter lower vertical dimension, flatter mandibular plane angle, and retroclined maxillary incisors.[4,30,31] Focusing on the skeletal aspects of deep overbite, Ceylan and Eroz found that among their 4 groups of patients with different bite depths, the gonial angle was significantly larger in the open bite group than in the deep bite group.[32] Previous studies also found a negative correlation with mandibular ramus length and the amount of

overbite;[9,33] a shorter ramus was thought to slow the eruption pattern of posterior teeth, leading to a deeper overbite.[34] Popovich especially found that Class II deep bite cases were more due to a short ramus height than Class I malocclusions.[21] However, others have contradicted this notion by reporting that ramus height either has no correlation with overbite[35] or that larger rami can actually lead to deeper bites.[36]

Regardless, a shorter lower facial height has been strongly associated with a deep overbite and should be taken into consideration when reviewing overall traits.[21,35,37] Enlow's counterpart analysis was used to study both deep and open bite cases. The following characteristics were noted for deep bite: a more acute gonial angle, an upward mandibular plane, flatter occlusal plane, deeper curve of Spee, a larger ANB, more maxillary protrusion, clockwise rotation of the palatal plane, and a posteriorly aligned ramus.[38] Baydas et al. also reported a statistically significant correlation between the depth of the curve of Spee and overjet and overbite.[39]

In regards to the amount of contribution from each variable of deep overbite, El-Dawlatly et al. attempted to quantify this after reviewing the lateral cephalometric radiographs of 124 patients. They concluded that the greatest causative factor of deep bite skeletally was the gonial angle, further emphasizing

the importance of the angulation of the ramus during growth. Dentally, the key factor was a deep curve of Spee, which points to the need for intrusion mechanics for the mandibular incisors of deep bite patients. Additionally, supraeruption of the maxillary incisors was the second largest dental component. It is recommended for clinicians to evaluate all components of deep bite for each patient individually to determine the best treatment plan and mechanics moving forward.[1]

Skeletal Growth and Dental Overbite

The terms “hyperdivergent” and “hypodivergent” were first introduced by Schudy to describe the facial patterns he was witnessing. Hypodivergent faces were characteristically low angle cases with decreased facial heights, whereas hyperdivergent facial patterns were associated with high mandibular plane angles and increased facial heights.[40] Schudy studied the lateral cephalograms of over 400 patients and documented the growth changes that would result in different rotations of the mandible. He found that the mandible’s rotation was dependent on the balance existing between the vertical growth and anteroposterior growth. If condylar growth was found to be greater than the vertical growth seen near the molar area, the mandible would rotate

counterclockwise, resulting in a more horizontal expression of growth, a decreased anterior facial height and an increased vertical overbite. The point of rotation was found to be at the most distal mandibular molar in occlusion, hence flattening the mandibular plane and deepening the bite. Schudy noted that this was ultimately what made deep overbite correction and retention difficult.[41]

Bjork utilized metallic implants in a longitudinal cephalometric study to show that the rotation of mandibular growth could be predicted. If the following factors were present, the mandible was more likely to have a forward rotation:[42]

1. a forward, vertically inclined condylar head
2. a mandibular canal following the curve of the angle of the jaw
3. a convex or rounded lower border of the mandible
4. a prominent chin and an upright symphysis
5. a larger interincisal angle
6. upright molars or premolars
7. a shorter lower anterior face

This anteroposterior pattern of growth of the mandible has been deemed to be a major determinant of the amount of overbite.[43] However, there has been controversy over the effects of growth on the overbite. Bjork found that during growth, there can be a general decrease in overbite even without treatment,[44]

while in another study he found that growth can contribute to an increase in overbite.[45] McNamara found that in a normally growing adolescent patient, a decrease in mandibular plane angle was established by 1 degree every 3-4 years.[46] As we continue to age, there is an increase in overbite due to the reduction in the Frankfort to mandibular plane angle and gonial angle.[47]

To account for the effects of growth in studies, there have been many ways to isolate measurements. Otto subtracted the change at the anterior nasal spine from the change at suprapogonion. This allowed him to only focus on combined incisor intrusion, as the extrusive effects of growth were removed.[48] Thompson evaluated changes in incisor and molar position relative to the overbite and occlusal plane. He then removed cephalometric measurements related to growth to focus solely on treatment effects using the Begg technique.[49] In a study on the effects of orthodontic extraction, Chua controlled for growth effects by using the Michigan Growth Standard to normalize the ANS-Me measurements.[50] Generally, most studies attempt to use subjects of the same age group to control for growth effects.[15]

Treatment of Deep Bite

Because of the varying facial types and patterns of growth, each patient's method of treatment should be considered individually with respect to their malocclusions and desired treatment outcomes.[4,51] According to Proffit, the first step in assessing the vertical skeletal pattern in a patient is to evaluate the anterior facial height. A lower facial height, measured from the anterior nasal spine to menton, that is 55% of the total anterior facial height is considered to be a balanced face.[14]

The second element to evaluate would be the parallelism of the mandibular, occlusal and palatal planes - this would again indicate the amount of vertical development.[14] If the posterior facial height is greater than the anterior facial height, overbite will be difficult to correct and Schudy recommends banding the mandibular second molars. He also suggests moving maxillary molars distally, avoiding extractions when possible, and having an extended retention phase.[40]

Overall, there are three main treatment strategies for deep bite correction, excluding a surgical option; extruding the posterior teeth, proclining the anterior teeth, and intruding the incisors.[4,52] Extruding the posterior teeth can be an effective way of opening the bite.[36,51,53] One millimeter of molar

extrusion is thought to effectively reduce incisal overlap by 1.5-2.5 mm. A common way to achieve this is through leveling a deep curve of Spee with straight continuous archwires.[54] Other alternatives include using a mandibular reverse curve of Spee archwire, a maxillary exaggerated curve of Spee wire, altering bracket positions,[4] or creating progressive step bends.[55]

Bite plates as well as bonded lingual devices have also been used to extrude posterior teeth.[26,56,57] Hans found that bite plates allowed eruption of the posterior teeth without intrusion of the lower incisors, thereby increasing lower vertical facial height.[58] For pubertal patients in permanent dentition, bite plates were also found to result in favorable outcomes through dentoalveolar changes such as upper and lower incisor tipping and no significant skeletal changes.[59] These methods are indicated in people with shorter lower facial heights, deeper Curve of Spee, and minimal or moderate incisor displays.[60,61] The stability of posterior extrusion is questionable in patients who are not growing.[4] Flaring the upper and lower incisors can also reduce the overbite through the rotation of the crowns.[62] This is especially effective for mild or moderate cases with lingually tipped incisors, such as Class II, Division 2 or Class III malocclusions. The concern with proclining the incisors is a lack of stability due to potential disturbances in the perioral neuromuscular balance.[63] Intrusion of the incisors is

moreso indicated for patients with a greater vertical dimension, large incision-stomion distance, and excessive interlabial gap.[60,61,64] Brachycephalic patients are especially good candidates for intrusion mechanics due to a larger mandibular alveolus that allows for successful intrusion of the incisors.[64]

The most common methods for incisor intrusion have been outlined by Burstone, Ricketts, Tweed, and Begg.[61,65,66,67] Burstone utilizes either a continuous intrusion arch or a 3-piece intrusion arch, depending on the needs of his patient. For a conventional intrusion arch, the posterior segment is anchored with a step up bend just mesial to the molar tube, bypassing the canines, and connecting the incisors as an anterior segment. The rectangular titanium-molybdenum alloy (TMA) wire is placed through the auxiliary tubes and the wire is brought down to the incisors, applying single forces of intrusion. If less flaring of the upper incisors is desired, then instead of a continuous wire, tip back springs are applied to the left and right sides and the bent hooks deliver an intrusive force distal to the lateral incisors.[68]

Ricketts intrusive utility arch was defined by step down bends between the first molars and the lateral incisors, allowing the wire to withstand the forces of mastication. Ricketts typically used rectangular cobalt chromium wires of different dimensions in the upper and lower arches.[69] Tweed mechanics involve

anchorage preparation with tip back bends, en masse retraction of teeth using intermaxillary elastics, and final detailing of tooth positions.[67]

When comparing 60 cases of Class II deep bite nonextraction cases treated with either Ricketts or modified Tweed techniques, both were effective in correcting the overbite while controlling the mandibular plane angle and anterior facial height. The mandibular incisors in the group treated by Ricketts did show more proclination and anterior bodily movement, with a greater amount of overbite relapse than Tweed. However, both groups resulted in similar amounts of lower molar extrusion and overall post-treatment changes were stable.[53]

Begg technique involves the use of differential forces in which light forces move the anterior teeth rapidly without adverse effects on anchorage teeth. This is made possible simply by anchor bends mesial to the molar tubes, with no need for anchorage preparation or headgear. The anchor bends also allow for opening of the bite via intrusion the anterior teeth. By contrast, heavier forces prevent anterior teeth from shifting and allow the posterior segments to be moved.[70] Though the wires and applications amongst these practitioners vary, they all generally include tipback bends at the molars and provide light continuous forces. [61,65,66,71] In addition, many can agree that most treatment plan

considerations for treating deep bite include a combination of all three – extruding posterior segments, proclining anterior segments, and intruding the anterior segments.[48,72]

Bite Turbos

In treating deep bite cases, the bite is frequently opened to prevent unwanted occlusal interferences with the mandibular brackets. This can be achieved with either fixed or removable bite planes prior to bonding the patient with bracket appliances; however, removable appliances largely require patient compliance.[73] Fixed devices for opening the bite include bonded lingual bite planes, anterior or posterior bite splints,[74] the Guray bite raiser,[75] bonded posterior occlusal bite blocks, and bite turbos.[76]

Chapman details the need for using several appliances in situations when the buccal segments are in neutroclusion, but the mandibular incisors still prevent the maxillary incisors from complete retraction due to deep overbite. He advised using a lower bite raiser to allow the maxillary incisors to retract, and then utilizing a maxillary bite plate to complete the overbite correction.[74] The Guray bite raiser is also indicated for use in deep bites and crossbites, when temporary bite opening is necessitated. Fabricated from .040” stainless steel

wire, the ends of the wire are inserted into a tube, with the occlusal portion adapted well to the anatomy of the maxillary tooth. The lingual aspect of the wire is bent and ligated to a lingual button bonded to the tooth; the ligation can be cut to check for occlusion. The molar tube serves as the hinging point for the ends of Guray bite raiser.[75]

Bonded posterior bite blocks eliminate the need for patient compliance, but still pose the risk of debonding in the case of retention issues. As recently as 2020, new appliances, such as the semi-fixed temporary bite raiser, have been fabricated to combat such situations. This appliance involves a “T” shaped spring to fix the posterior acrylic blocks to both buccal and lingual sheaths on the molar bands for further retentiveness.[77] Despite their success, all previously aforementioned appliances require either significant chair time, additional adjustment or emergency appointments, or laboratory procedures. For efficient and practical clinical applications, practitioners have increasingly been using “bite turbos” or restorative material built up onto lingual or occlusal surfaces of the teeth.[76] The use of band cements as build up material has particularly become more commonplace as it is hygienic, removes patient compliance factors, is less bulky, and results in less speech interference.[78,79]

When choosing an ideal adhesive material to use as build up material for bite turbos, it is essential to evaluate the shear bond strength of the adhesive. Whether adhesives are used for brackets or bands, the expectation is that the material will be easy to remove when needed, and able to resist both masticatory and orthodontic forces. In other words, the material should be able to last throughout the course of treatment. Because of these properties, this same adhesive can be used to add height to the occlusal and lingual surfaces of the desired teeth as bite turbos.[76]

There are different categories of bite turbos to be considered by the practitioner depending on preference and location as well. Bite turbos can be placed on the lingual surfaces of the anterior teeth or the occlusal surfaces of posterior teeth. They can be produced out of metal, but the term 'bite turbos' has now become more colloquially known as a resin-type of build-up material. Any resin material could likely be used for either the anterior or posterior, but clinicians should be wary of utilizing resins with the signature blue material on anterior teeth, as the blue hue could be transmitted through to the labial surfaces and become visible to the patient.[80]

Of the resin materials, there are various compositions: acrylic gels, compomer pastes, resin pastes, flowable resins, and glass ionomer cements.

Trade Gel (Dentsply Sirona) is an acrylic gel typically used for bite plates or modifications of casts. Popular compomer paste options include Ultra-Band-Lok (Reliance) and TruLock (Rocky Mountain), which are indicated for the use of cementing bands. They can bond to metal and include glass ionomer, which allows for the release of fluoride. The downfall with these materials, as previously mentioned, is the blue color. Twinky Star (VOCO) is usually used for restorations in deciduous teeth, but is also an acceptable compomer paste option. Within the category of resin pastes, the more common ones include the bracket paste Blugloo (Ormco) and the lingual retainer resin Transbond LR (3M Unitek). The disadvantage to these materials is that they abrade the opposing occlusion. FlowTain (Reliance) is a popular flowable resin for the use of lingual retainers, but it also has the unfortunate effect of wearing down the opposing dentition. A resin modified glass ionomer (RMGI) such as Ketac (3M Unitek) can be used for bite turbos, but it is more difficult to remove from the teeth.[80]

Kilinc and Sayar evaluated the shear bond strength of three different types of adhesives in the application of bite turbos: Group I received Transbond Plus, Light Cure Band Adhesive (3M Unitek); Group II had Transbond XT, Light Cure Adhesive (3M Unitek); Group III consisted of Transbond Supreme LV, Low Viscosity Light Cure Adhesive (3M Unitek). Forty-eight extracted molars were

prepared with pumice and 37% phosphoric acid etch. The molars were placed in cylindric molds and filled with the respective adhesives and cured for 20 seconds. Shear bond strength tests were performed with a Universal Testing Machine and teeth were evaluated under a stereomicroscope. The teeth were evaluated and recorded by the adhesive remnant index (ARI) scoring. They found no significant difference between the groups, but did find that Transbond XT had the highest bond strength of 12.61 MPa while Transbond Plus had the lowest bond strength of 10.82 MPa. As a general note, the study found that all three adhesives were acceptable for use as bite turbo materials, and etching enamel surfaces was sufficient for the adhesive lasting throughout the course of treatment.[76]

The recommendation for the placement of bite turbos, especially for the anterior, are not to have the practitioner inject the material freehandedly, as different amounts of resin could extrude with no appropriate control. The clinician can opt to utilize a prefabricated mold; however, this would be an additional cost for the doctor to incur. To circumvent expenses, the orthodontist could fabricate their own mini-molds out of existing bond brush holders, acrylic teeth, disc separators, and silicone guns as outlined in Alsheikho and Jomah's

paper. Similar to the previous study, it is suggested to use 37% phosphoric acid etch for 15 seconds prior to applying any resin adhesives.[80]

The notion of posterior bite elevators being used for treating deep bites can be counterintuitive, as previous studies with posterior bite blocks have shown that they can be used for controlling the posterior eruption of molars in high angle open bite patients.[81] In Macaca monkeys, varying degrees of posterior bite blocks were used to evaluate skeletal and dentoalveolar changes. Results showed that the maxilla was displaced in an upward and forward direction, rather than downward and forward, and the maxillary molars were either inhibited from erupting or were intruded.[81,82] The concerns with posterior bite turbos are that the patients are temporarily introduced to occlusal trauma, precluding them from having a functional bite. To have an optimized functional occlusion, there should be an even distribution of simultaneous intercuspal contact, allowing for appropriate axial loading of occlusal forces during mastication. However, the band cement is typically placed bilaterally on posterior teeth, resulting in only two occlusal contacts.[83]

In certain orthodontic systems, bite turbos are used as an integral part of the treatment mechanics, and not just as an adjunct. For example, the system outlined by Pitts regularly utilizes the strategic placement of anterior or posterior

bite turbos to allow for disarticulation of the teeth and the immediate use of light short elastics. The thought is that the bite turbos serve as 'occlusal guides' which allow for rotation of the occlusal plane in whichever direction is deemed necessary. In deep overbite patients, early posterior bite turbo placement allows for eruption of the lower molars and extrusion of the upper anterior teeth while promoting a clockwise rotation. In combination with the intentionally placed brackets to protect the smile arc, the use of bite turbos with is thought to help rotate the occlusal plane, rather than intrude the posterior segments and deepen the bite. Throughout the course of treatment, it is recommended that the clinician continue to evaluate the placement of the bite turbos and move them accordingly. In a deep bite case, the bite turbos may be removed from the posterior teeth and placed anteriorly to continue allowing for eruption of the lower molars without deepening the bite.[84]

The clinical significance of utilizing resin adhesives as posterior bite turbos has not been greatly investigated, as it is more of a recent phenomenon. Studies have shown that the effect of the muscles of mastication[85] and masticatory function in general were reduced immediately following the placement of posterior bite turbos.[83] Moreover, the vertical dental and skeletal effects of temporary bite raising have only been evaluated with anterior bite

turbos.[86] In a recent masters thesis by Meky, the effect of bite turbos on mandibular anterior bracket failure rate was studied. He found that the bite turbo group had a 6% failure rate compared to an 11% failure rate in the non-bite turbo group. This difference was not statistically significant and was skewed due to the small sample size of the study.[87] However, studies like these do suggest a growing interest in the clinical applications of bite turbos and a need for further investigation about its effects.

Assessment of Vertical Tooth Movement

In order to fully understand the anterior bite turbo study executed by Elbarnashawy, a review of the terminology regarding vertical incisor movement is necessary. “Tipping depression” was first coined in 1962 by Thurow, describing the downward and forward movement of the incisal edges of the mandibular incisors along an arc of rotation. This clinically resulted in the appearance of intrusion.[88] Other terms such as “true intrusion”[89] and “pseudo-intrusion”[61] were used to delineate bodily incisor movements from labial tipping. Liu and Herschleb described pure intrusion as the vertical displacement of the center of resistance of the tooth while the axial inclination stays constant. They defined

this by utilizing a coordinate system to separate the vertical and horizontal movements of the tooth.[90]

Similarly, other studies have used methods such as running perpendicular lines from the anterior nasal spine to the upper incisal edge, and the mandibular plane to the lower incisal edge to measure vertical movements of incisors.[51,91] Otto used templates to register the incisal edges of the teeth and translated them along their long axes to measure distances between the root apices pre- and post-treatment.[48] Some measured intrusion from the tooth's center of resistance,[90] while others measured from the center of the tooth.[61] Enlow outlined a method in his "counterpart analysis" to be able to evaluate whether a face was balanced or unbalanced based on its vertical and horizontal dimensions. The counterpart analysis focused on the individual aspects of the cranio-mandibular-cervical structure and their shape, location, and development. When comparing each feature to its counterpart, it was considered to be harmonious and ideal if there was only 0 to 2.5 mm difference between the corresponding parts.[92]

In terms of vertical analyses to evaluate overbite correction specifically, various authors have attempted to isolate movements in a systematic manner based on regional and overall superimpositions of lateral cephalograms. Barton

used a pre-treatment tracing containing a coordinate system of lines placed beneath the post-treatment tracing. The cephalograms were superimposed upon the outline of the anterior cranial fossa.[93] Simons and Joondeph transformed the cephalogram tracing into a 'facial polygon,' superimposed on the plane of the sphenoid bone, the cribriform plate of the ethmoid, and the curvature of the great wings of the sphenoid. The X axis was the initial Frankfort horizontal (FH) line, and the Y axis was the line perpendicular to the initial FH line intersecting the sphenoid plane-cribriform plate contour midway between the curvature of the great wings of the sphenoid.[94]

The issue with the aforementioned methods was that they were limited to qualitative results and were not able to report individual amounts of tooth movement. True bodily intrusion or labiolingual tipping movements were not separated as different components, and therefore they lacked an adequate way to quantitate the relative contributions of orthodontic dental changes, skeletal changes, and growth. Johnston attempted to visualize anterior-posterior skeletal and dental components of the molar and the total overjet change using his pitchfork analysis in 1986. In his analysis, he measured growth and displacement of the maxilla and mandible relative to the cranial base. The cephalogram was registered at the SE point, or the intersection of the cribriform plate and the

greater wing of the sphenoid bone. The tracing was oriented to be parallel to the mean functional occlusal plane.[95]

Dental movements were measured on the respective regional superimpositions. The apical base change (ABCH) was measured as the difference between the sagittal displacement of the maxilla versus the mandible. The elegance of the pitchfork analysis was that all skeletal and dental changes could be added together to reveal an algebraic sum of the total treatment change in the molar relationship and incisal overjet. A positive summation indicated an improved relationship (eg. forward growth of the mandible or distal movement of the maxillary molars), whereas a negative result meant that the relationship worsened (eg forward growth of the maxilla or mesial movement of the maxillary dentition). The analysis became even more nuanced when considering that trigonometry was involved with calculating the tipping movements of the incisors.[95]

Case Western Vertical Pitchfork Analysis

In a similar manner, in 1987 Kishiyama recognized a need for determining individual contributions from dental changes, skeletal changes, and growth (eg. isolating dental intrusion separately from the vertical changes occurring due to

dental tipping). Together with Hans, they formed a novel cephalometric analysis at Case Western Reserve University that isolated vertical dental movements from skeletal changes. The initial and final lateral cephalograms were traced on acetate paper with pencil. The landmarks used for tracing to allow for the registration of points are listed below:[96]

1. Foramen rotundum in the pterygomaxillary fissure
2. Three (3) mm above orbitale
3. Posterior nasal spine (PNS)
4. Anterior nasial spine (ANS)
5. Center of resistance (CR) of the upper incisor
    a. CR was arbitrarily set at 40% of the distance from the alveolar crest to the root apex[90] and transferred by a template registered on the incisal edges
6. Incisal edge of the upper incisor
7. Most posterior occlusal point of the last fully erupted maxillary and mandibular molars
8. Most anterior maxillary/mandibular 1st premolar occlusal contact
9. Incisal edge of the lower incisor
10. CR of the lower incisor

11. Articulare (Ar)

12. Gonion (GO)

13. Menton (Me)[96]

Lateral cephalograms pre and post treatment were superimposed on the anterior cranial base landmarks outlined by Bjork[44], and fiducial lines were transferred to the superimpositions. Registration points were punched with an Alvin divider and then digitized on a Summagraphics pad which oriented the points into a coordinate system, allowing them to define and measure 6 linear and 1 angular measurements. These were calculated by the DentoFacial Software 5.1 program. Linear measurements were made perpendicular to the fiducial reference line, which was constructed from the pterygoid point to a point 3 mm above orbitale.[96] This line was chosen as it represents the path of the maxillary neve and approximately parallels the palate during development.[92] The gonial angle was measured as the shape of the mandible was considered to be important in deep overbite patients.[33] The six linear measurements made are as follows:[96]

- Measurement 1 (M1): the distance from the reference line to ANS
- Measurement 2 (M2): the distance from the reference line to CR of the maxillary incisor

- Measurement 3 (M3): the distance from the reference line to the incisal edge of the maxillary incisor
- Measurement 4 (M4): the distance from the reference line to the incisal edge of the mandibular incisor
- Measurement 5 (M5): the distance from the reference line to the CR of the mandibular incisor
- Measurement 6 (M6): the distance from the reference line to Me

Then, the measurements were subtracted from each other to find the respective dental or skeletal changes under investigation:[96]

1. Maxillary skeletal change (MXSK) = M1
2. Bodily movement of the maxillary incisor (BUI) = M2 – M1
3. Tipping of the maxillary incisor (TUI) = M3 – M2
4. Tipping of the mandibular incisor (TLI) = M5 – M4
5. Bodily movement of the mandibular incisor (BLI) = M6 – M5
6. Mandibular skeletal change (MNSK) = M6 – M1
7. Dental overbite (OB) = M3 – M4

Kishiyama used this CWRU Vertical Pitchfork Analysis to examine the effects of different facial indexes (euryprosopic, mesoprosopic, leptoprosopic) on treatment response when orthodontically correcting excessive overbite. He

compared 94 treated patients from the CWRU Orthodontic department to 93 untreated control patients from the Bolton-Brush Growth Study. He found that extreme facial types were neither opposite in treatment effect nor in growth pattern. Bodily movement of the lower incisor and anterior mandibular skeletal change did not appear to be related to facial type whatsoever. He noted that headgear was able to alter maxillary skeletal changes that typically occurred in growth, and that the maxillary incisors showed unfavorable tipping in extraction cases. In euryprosopic facial types, intrusion of the mandibular incisor was the most contributing factor to overbite correction, confirming that molar extrusion is difficult in low-angle individuals. Mesoprosopic individuals achieved more than half of their overbite correction through both upper and lower incisor intrusion. For leptoprosopic facial types, overbite was mostly corrected through tipping and bodily intrusion of the lower incisors, and mandibular skeletal changes.[96]

This vertical analysis was used by many other studies following its inception. In 1990, Parker utilized a modified version of the analysis; in contrast to Kishiyama's use of Pt-Orbitale+3 line, Parker superimposed his tracings on the sphenoethmoidal junction and the anterior cranial base. This method was considered to be incredibly accurate as the area employed was assumed to be extremely stable and unchanged in shape and size over time. The fiducial

horizontal reference line was still constructed from the Pt point to a point 3 mm above orbitale and transferred to all tracings. In addition, Parker added the mandibular plane angle (MPA) as a measurement.

Parker compared 45 cases treated with cervical headgear and tandem mechanics to 40 untreated controls from the Bolton Brush Growth Study. He found that the cervical pull facebow headgear reduced the overbite and increased the maxillary skeletal height significantly in all facial types. Significant upper incisor intrusion and increases in MPA occurred in all facial types.[97] To supplement Parker's findings, Hans et al. also compared this group to 50 patients treated with a bionator appliance and matched to control subjects from the Bolton-Brush Growth Study. The results revealed that compared to the headgear and tandem treatment, the bionator corrected the overbite more through relative intrusion of the incisors and mandibular skeletal change.[98]

In addition to investigating the vertical effects of treating deep bite,[15] treatment of open bites[99,100] and extraction cases[99,101] were also reviewed using this analysis. Dietrich evaluated open bite correction treated with four bicuspid extractions and fixed edgewise appliances. For open bite, the convention of signs used in the analysis were opposite from deep bite, as positive numbers indicated that the overbite was changing in the desired direction. He found that most of

the open bite correction was through lingual tipping of both the upper and lower incisors, with untreated open and deep bite patients showing surprisingly similar skeletal and dental changes.[99]

Damon used the CWRU vertical analysis to evaluate the effects of Tweed mechanics with four first bicuspid extractions in deep bite patients. In contrast to Dietrich's findings, he found that most overbite correction was achieved through bodily intrusion of the upper and lower incisors. He also confirmed that utilizing Tweed mechanics enables the practitioner to effectively limit vertical skeletal development. These results were supplemented by Groisser's findings in patients treated with four first molar extractions, essentially testing the 'wedge hypothesis.' Remarkably, the extraction of four first permanent molars did not have an effect on the vertical occlusion in the sample, and it was determined that both treatment strategies of extractions showed acceptable vertical control of mandibular growth.[15]

Bazzucchi focused on the effects of a two-phase nonextraction treatment in the correction of open bites. In the initial phase, the subjects were treated with an active vertical corrector (AVC), a magnetic appliance that reportedly could result in intrusion of the posterior teeth through the forces of repelling magnets. The second phase involved treatment with conventional fixed

appliances. Though she did not find statistically significant changes between treated and control subjects in any variables within phases, the overbite throughout the entire treatment was significantly improved. Clinically, changes were evident in lingual tipping of the mandibular incisors, extrusion of the incisors, and relative mandibular vertical growth.[100]

Most recently, Elbarnashawy investigated the outcome of treating deep bite patients with pre-adjusted edgewise appliances concomitantly with anterior bite turbos. He utilized the same cephalometric analysis that was historically used at CWRU, but he digitized the process. In his study, he examined 30 patients pre-treatment, post-treatment, and compared to the Bolton Brush Growth Study control group. The treated patients all had lateral cephalograms obtained by the same Carestream machine, so the magnification of all images was consistent at 8%. The control group was retrieved from the digital library of the Bolton Brush legacy collection after being scanned via a film digitizer. The images were digitally traced on the Dolphin software program and calibrated using the x-ray machine's fixed 30 mm ruler. For the control group, the registration points punched into the radiographic films prior to digital scanning were used for calibration.[86]

The center of resistance for this study was arbitrarily set at one third of the root length from the apex to the cemento-enamel junction. This was added as a custom landmark to the ceph analysis in Dolphin, and the incisor template with the same form and size from Time 1 was used to transfer the CR point to Time 2. For this digitally modified version, the cephalograms were superimposed for best fit of the greater wing of the sphenoid, the planum sphenoidale, and the anterior wall of sella. There was also no longer a necessity for the fiducial line to be constructed; Dolphin was able to create a Cartesian coordinate system allowing for the origin point to be coincident in both tracings.

Elbarnashawy found that there were statistically significant changes in the bodily movement of the upper incisor, tipping of the upper incisor, tipping of the lower incisor, bodily movement of the lower incisor, and mandibular skeletal changes. He concluded that anterior bite turbos were an acceptable treatment option for individuals with a decreased lower facial height and deep overbite.[86] Though the clinical effects of using anterior bite turbos are better understood, there is still much to be investigated regarding the vertical effects of posterior bite turbos used concurrently with fixed appliances in the treatment of deep bite patients.

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STATEMENT OF THESIS

The purpose of this study was to evaluate the vertical cephalometric effects of utilizing posterior bite turbos in conjunction with fixed appliances in the treatment of deep bite malocclusion.

MANUSCRIPT FOR PUBLICATION

The following paper was prepared according to the guidelines published in the

American Journal of Orthodontics and Dentofacial Orthopedics

CEPHALOMETRIC EVALUATION OF USING POSTERIOR BITE TURBOS AND PREADJUSTED EDGEWISE APPLIANCES IN DEEP OVERBITE CORRECTION

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ABSTRACT

INTRODUCTION: To purpose of this study was evaluate the vertical outcomes of correcting deep overbite in growing patients using posterior bite turbos concurrently with preadjusted edgewise appliances.

METHODS: Thirty-four subjects were evaluated at pretreatment (T1) and posttreatment (T2) and compared to an untreated control group from the Bolton Brush Growth Study Collection (CWRU, Cleveland, Ohio). Subjects were matched based on age and sex. The Case Western Reserve University (CWRU) vertical cephalometric analysis was used to separate tipping movements of upper (TUI) and lower incisors (TLI), bodily movement of upper (BUI) and lower incisors (BLI), and anterior maxillary (MXSK) and mandibular skeletal changes (MNSK).

RESULTS: The overbite (OB) was reduced significantly in the treated group ($P \leq$ .001) (2.2mm) compared to the control group. The change in the TUI ($P \leq .001$) (0.9 mm) was statistically significant. Much of the deep overbite was corrected through labial tipping of the upper incisors, followed by labial tipping of the lower incisors and maxillary skeletal control. Lower incisor intrusion and mandibular skeletal change also helped to reduce overbite. However, there was not a significant increase in anterior facial height.

CONCLUSIONS: Growing patients with deep overbite were treated efficiently using posterior bite turbos in conjunction with preadjusted edgewise appliances. Special consideration should be taken when treating individuals with reduced lower anterior facial height, as posterior bite turbos may effectively control the vertical maxillary and mandibular skeletal dimensions.

INTRODUCTION

Deep overbite (OB) has long been considered both a common and challenging form of malocclusion to treat. The etiology of a deep overbite has been found to be multifactorial, with contributions from dental, skeletal, and muscular components. There are various ways to treat patients with deep overbite, but ultimately the following must occur: intrusion and labial tipping of the incisors, molar eruption, and maxillary and mandibular skeletal changes.[1,2]

In treating deep overbite cases, the bite is frequently "opened" to prevent unwanted occlusal interferences with the mandibular brackets. This can be achieved in a two-phase treatment with a removable bite plane prior to bonding the patient with bracket appliances; however, they largely require patient compliance and extend treatment time.[3] Fixed devices for opening the bite include bonded lingual bite planes, bonded posterior occlusal bite blocks, and "bite turbos."[4,5]

Bite turbos have risen in popularity due to their convenience of fabrication, efficiency, low visibility, and removal of patient compliance factors.[6] Turbos are commonly placed on the lingual surfaces of the upper incisors using resin-type material. A recent study investigating growing patients with deep bite revealed that anterior bite turbos contribute to significant intrusion and labial

tipping of incisors.[7] This was similar to the results of a two-phase treatment utilizing removable bite planes in which the OB was reduced through upper and lower incisor tipping.[8]

Counterintuitively, practitioners have also been opting to place the turbos on the occlusal surfaces of the posterior teeth. Reasons may include patient comfort, large anteroposterior discrepancy precluding the use of anterior turbos, proximity to the area of bracket interference or crossbite, and personal preference. The purpose of this study was to determine the vertical effects of posterior bite turbos in conjunction with preadjusted edgewise appliances in growing patients. The Case Western Reserve University (CWRU) vertical pitchfork cephalometric analysis was used to separate incisor movements from skeletal changes.

METHODS

Subjects

This retrospective study examined the cephalometric records of 123 patients treated at the CWRU orthodontics clinic (Cleveland, OH). The Institutional Review Board of Case Western Reserve University (IRB #2023-1349)

approved this study. Each patient was treated with posterior bite turbos placed on the occlusal surfaces of either the upper or lower premolars or molars bilaterally, and 0.022 x 0.028-inch brackets. Both round and rectangular archwires of nickel titanium, stainless steel, and titanium-molybdenum alloy were used throughout treatment. Elastics were used to correct anteroposterior discrepancies.

Thirty-four sets of lateral cephalograms fulfilled the inclusion criteria: pretreatment (T1) and posttreatment (T2) cephalograms of diagnostic quality, orthodontic treatment using posterior bite turbos, lower incisal edge at or beyond the cingulum of the upper incisor, T1 age of 11-17 years, and positive anterior/posterior overjet. Subjects were excluded if they had at least one of the following criteria: insufficient radiographs for diagnosis, outside the age range of 11-17 years, extractions or missing teeth (not including third molars), intrusion arches, reverse curve of Spee (RCS) wires, temporary anchorage devices, any functional orthopedic appliance, craniofacial syndromes or orthognathic surgery. The control group consisted of thirty-four untreated subjects matched for age and sex from the Bolton Brush Growth Study collection (Cleveland, OH).[9]

Image Collection

Treatment radiographs were taken on a CBCT machine with subjects in a natural head position and biting in centric occlusion. The CBCTs were used to construct lateral cephalograms oriented at the mid-sagittal line, with an orthogonal projection of 0% magnification. The investigator (MC) digitized the images after deidentification. Radiographs for the control group were retrieved from both the digital and physical libraries of the Bolton Brush legacy collection. All control group lateral cephalograms were scanned with a film digitizer (VIDAR DosimetryPRO Advantage, Vidar Systems Corp., Herndon, VA). The same investigator performed all constructions and measurements.

Technical Details

One investigator (MC) traced all images digitally using imaging software (Dolphin version 12.0, Patterson Dental Supply INC., St. Paul, MN). The following landmarks were identified on each cephalogram: anterior nasal spine (ANS), center of resistance of the maxillary and mandibular central incisors (CRU1, CRL1), incisal edges of the maxillary and mandibular central incisors (IEU1, IEL1), and menton (Me). T1 and T2 images were superimposed digitally on anterior cranial base structures such as the anterior wall of sella, the greater wing of sphenoid, and planum sphenoidale. This digital method was outlined by

Elbarnashawy,[7] which modified the hand-traced version of the CWRU cephalometric analysis in other studies.[2,10,11] The software automatically constructed a Cartesian coordinate system for the superimpositions with the origin point (0,0) coincident at orbitale (Or). Because of this layout, the fiducial lines used in traditional studies with lightboxes and acetate paper were no longer necessary.[2,10,11,12]

Figure 1 reveals the six linear and two angular variables that result from the CWRU analysis; the schematic involves dental, skeletal, and angular changes. Maxillary skeletal change (MXSK) is the vertical difference between ANS at T1 and T2. Bodily movement of the upper central incisor (BUI) is the vertical distance between ANS and CRU1. Tipping of upper central incisor (TUI) is the vertical distance between CRU1 and IEU1. Tipping of the lower central incisor (TLI) measures between the IEL1 and CRL1. Bodily movement of the lower central incisor (BLI) is the distance between CRL1 and Menton. Mandibular skeletal change (MNSK) is the vertical change between ANS and Menton. Mandibular plane angle was measured as the angle between the Sella-Nasion plane and the mandibular plane (SN-MPA). Gonial angle (Ga) was the angle formed between Articulare, Gonion, and Menton (Ar-Go-Me).

Convention of Signs

Dental and skeletal movements that reduced the vertical overbite received a positive sign (+), while movements that increased the overbite received a negative sign (-). As an example, the tipping movement of the upper incisor (TUI) towards the occlusal plane (ie, retroclination) would be assigned a negative sign. The changes in the linear variables were summed together to result in the net change in overbite using the following formula: $\Delta OB = \Delta MXSK + \Delta BUI + \Delta TUI + \Delta TLI + \Delta BLI + \Delta MNSK$. In addition, the change in anterior facial height (AFH) was calculated by adding the changes in MXSK and MNSK together: $\Delta AFH = \Delta MXSK + \Delta MNSK$.

Statistical Analysis

The personal computer version of the Statistical Package for the Social Sciences (SPSS, Chicago, IL) was used to analyze data. The Shapiro-Wilk test was applied to assess the normality of each variable. Descriptive statistics were assessed to evaluate the effects of sex and age matching and to identify any dentoalveolar differences between the treated and control subjects. The statistical significance between the means of the two groups was calculated using two-tailed paired *t*-tests, with Alpha ≤ 0.05 and Beta ≤ 0.2 for all tests.

To account for tracing and measurement error by the investigator, ten subjects (five from the treated group and five from the control group) were randomly selected and traced for a second time at T1 and T2. The six linear and two angular variables were measured again, and the two sets of tracings and measurements were compared to each other using intraclass correlation coefficients.

RESULTS

Thirty-four subjects, 11 male and 23 female, fulfilled the inclusion criteria. There were 29 Caucasians, 4 Hispanics, and 1 African American in the treated group. The mean age at T1 was 13.6 years and the mean age at T2 was 16 years. 28 patients were Angle Class I and 6 patients were Angle Class II. There were 31 subjects with a mesocephalic facial pattern, 2 dolichocephalic, and 1 brachycephalic. Control subjects were chosen from the Bolton Brush Growth Study Collection and matched on gender and age to the treated group (Table 1).

At T1, there were no variables that showed statistically significant differences between the groups ($P \leq .001$) (Table 2). The Shapiro-Wilk test showed that seven variables (MXSK, BUI, TUI, TLI, BLI, MNSK, Go) met parametric assumptions. Two-tailed paired *t*-tests were utilized to evaluate the presence of

significant differences between those variables. For the remaining two variables (OB and SN-MPA) which were non-parametric, the Wilcoxon signed rank test was used.

In the treated group, the TUI contributed significantly ($P \leq .001$) to a reduction in deep overbite. Other variables such as MXSK, TLI, BLI, and MNSK appeared to help reduce overbite, but were not statistically significant. There was a significant 1.2 mm decrease in overbite in the treated group and -1.0 mm increase in overbite in the control group, resulting in a net OB change of 2.2 mm ($P \leq .001$). Repeat measurements of the tracings showed mean intraclass correlation coefficients between 0.953 and 0.993.

DISCUSSION

The purpose of this study was to quantify relative contributions of deep overbite correction in growing individuals treated with preadjusted edgewise appliances and posterior bite turbos. The CWRU vertical pitchfork analysis allows for a comprehensive way to readily compare the effects of various treatment protocols for deep overbite patients. In this way, the practitioner overseeing treatment can make better clinical decisions based on the patient's characteristics prior to treatment and the desired facial and dental changes. The

strength of using the CWRU vertical analysis is the previously recorded literature of findings for different biomechanical systems.

The aforementioned studies include investigations into deep bite correction with cervical pull headgear, Bionator therapy, Herbst appliance therapy, Tweed edgewise mechanics with extraction of first premolars, continuous arch mechanics with extraction of first premolars, and non-extraction treatment with anterior bite turbos.[2,7,12,13] The CWRU analysis has also been used to evaluate open bite correction with an active vertical corrector and extraction of first molars.[2,11] The same methodology was used in each mode of treatment to isolate the dental and skeletal changes that contributed to the final overbite result. Unlike most of the previous studies evaluating the correction of deep overbite, the results of the present study did not observe a significant increase in lower vertical facial height. The results were more similar to those of the Tweed edgewise mechanics with first premolar extractions. Both systems were able to control the vertical facial height without increasing the mandibular plane angle or gonial angle significantly. However, the majority of overbite correction in Tweed mechanics relied on bodily intrusion of the upper and lower incisors, while the posterior bite turbo mechanics mainly resulted in upper incisor tipping.

When compared to preadjusted edgewise appliances with anterior bite turbos, there was a much less significant reduction in overbite, as the initial overbite for the treated subjects was greater with anterior bite turbos.[7] This potentially suggests that posterior bite turbos are considered for use in patients who may not necessarily have a deep overbite, but rather are placed due to occlusal interferences with brackets of individual teeth. All parameters evaluated with anterior bite turbos contributed to the decrease in overbite, with the greatest contribution coming from mandibular skeletal change and labial tipping of the lower incisors. The lower incisor tipping may have been more significant due to the greater number of Angle Class II patients in the anterior bite turbo study.

The facial pattern of individuals should also be taken into consideration when interpreting the results of fixed appliances with posterior bite turbos. As clinicians are aware, there is a strong correlation between facial type and dental overbite, and patients should therefore be treated with a customized approach.[14,15] The average SN-mandibular plane angle for the treated group was $32.9 \pm 5.4^{\circ}$ and the average gonial angle was $125.5 \pm 6.5^{\circ}$, suggesting that a majority of subjects had normodivergent facial growth patterns. If the group under investigation was comprised of more extreme facial patterns, the results

would likely be affected. A study evaluating removable posterior bite planes in skeletal open bite malocclusions (SN-MPA > 36°) found that the mandibular plane angle was significantly reduced, the posterior facial height was significant increased, and the change in anterior facial height was insignificant after treatment.[16]

The effects of posterior bite turbos on the MNSK, AFH, SN-MPA and Ga were negligible, suggesting the potential ability to control the vertical skeletal dimensions. These results are similar to those of Iscan and Sarisoy, who found that passive posterior bite blocks were effective in controlling the increase of vertical facial heights. The study also revealed that an increase in the posterior bite-block height did not affect the amount of overbite correction; however, there were significant differences in the rotation of the mandible and the gonial angle.[17] The amount of resin-material placed on the occlusal surfaces for posterior bite turbos could have an effect on the dental and skeletal vertical changes. Duration of the turbos would likely also impact the results. The treated group saw a net reduction in overbite by 2.2 mm, which was primarily attained by labial tipping of the upper incisor (Figure 2). Percentage contributions of the other variables can be seen in Figure 3.

Limitations

Limitations of this study design include a variety of treatment providers, and bite turbo locations, heights, and treatment durations.

CONCLUSIONS

- Deep overbite correction was achieved ($P \leq .001$) efficiently using posterior bite turbos with preadjusted edgewise appliances.
- Overbite correction was mainly achieved through significant labial tipping of the upper incisor ($P \leq .001$).
- Posterior bite turbo mechanics with fixed appliances should be considered in patients with deep overbite, but practitioners should take caution in individuals with decreased anterior facial height.

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FIGURES

Figure 1. Schematic diagram compromised of dental, skeletal, and angular variables.

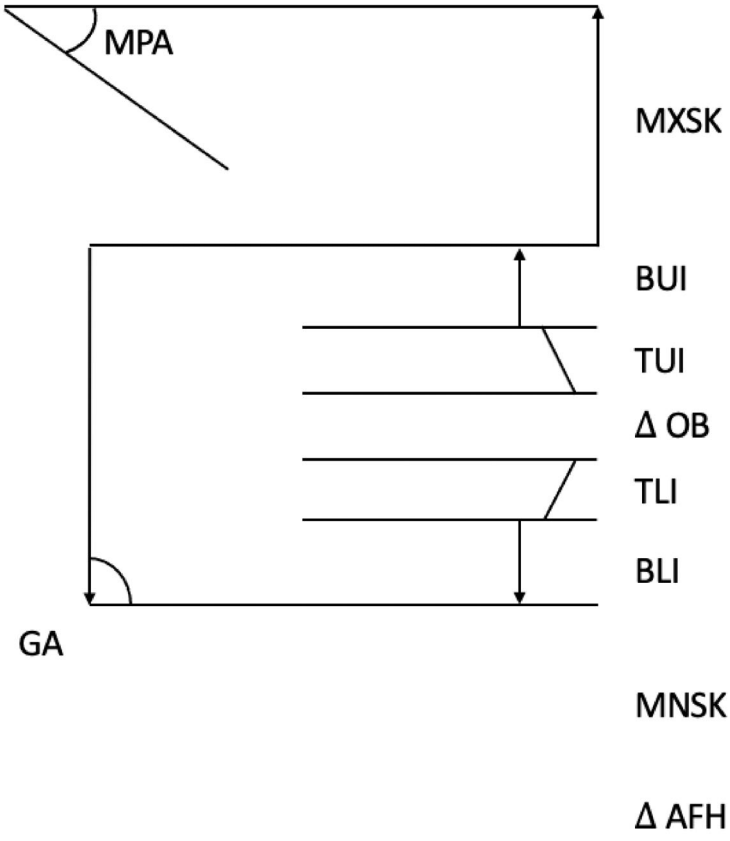


Figure 2. Schematic diagram showing the overall net changes between both groups (treated minus control).

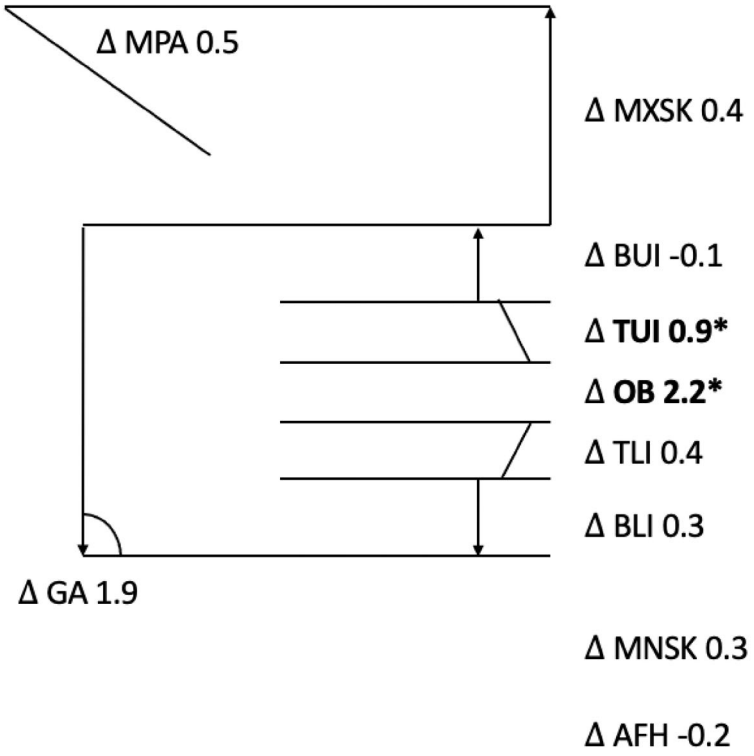
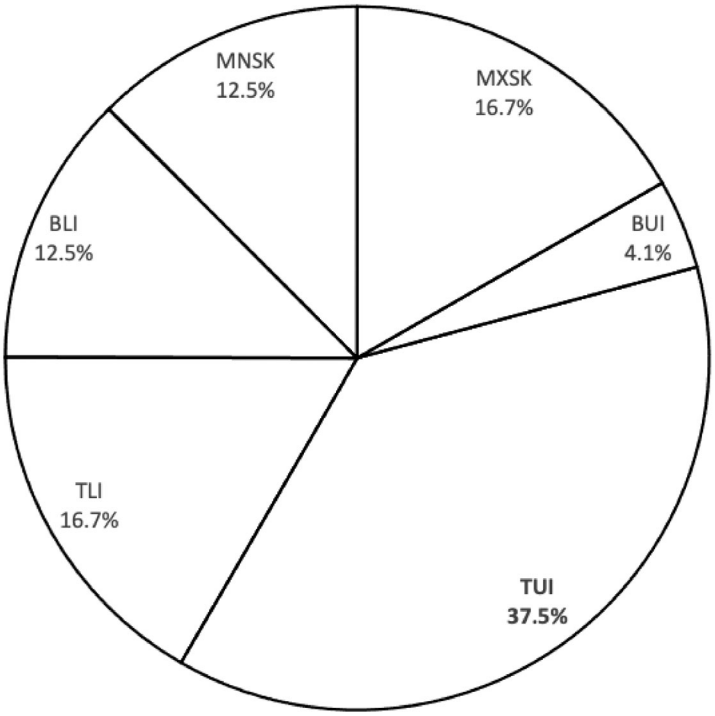


Figure 3. Percentage contribution to overbite correction by each variable.



TABLES

Table 1. Description of Treated and Control Groups

	Treated	**Control**
Total Sample	34	34
Girls	23	23
Boys	11	11
Age at T1 (y)	13.6 ± 1.8	13.7 ± 1.8
Age at T2 (y)	16.0 ± 1.9	16.0 ± 1.9
Caucasian	29	34
Hispanic	4	0
African American	1	0
Angle Class I	28	21
Angle Class II	6	11
Angle Class III	0	2
Overbite at T1 (mm)	4.2 ± 1.6	3.9 ± 2.0
Overbite at T2 (mm)	2.4 ± 1.4	3.9 ± 1.4
Dolichocephalic	2	10
Mesocephalic	31	23
Brachycephalic	1	1

Table 2. Comparison Between Treated and Control Groups at T1

Variable	Treated Means (T1)	Control Means (T1)	*P* Value	Significance
MXSK	21.6 ± 3.4	23.3 ± 4.1	.10	NS
BUI	8.3 ± 1.9	7.9 ± 3.0	.53	NS
TUI	18.0 ± 1.5	18.7 ± 1.6	.04	NS
TLI	14.4 ± 1.3	15.2 ± 1.8	.03	NS
BLI	21.8 ± 2.4	21.3 ± 2.8	.45	NS
MNSK	58.4 ± 3.7	59.2 ± 6.2	.52	NS
OB	4.2 ± 1.6	3.9 ± 2.0	.61	NS
Ga	125.5 ± 6.5	126.0 ± 9.5	.81	NS
SN-MPA	32.9 ± 5.4	34.5 ± 6.6	.39	NS

All measures are in millimeters except Ga and SN-MPA, which are in degrees

* Significant $P \leq .005$ between treatment and control groups
** Significant $P \leq .001$ between treatment and control groups

Table 3. Comparison of Changes Between Treated and Control Groups at T2

Variable	Treated Means (T2-T1)	Control Means (T2-T1)	*P* Value	Significance
MXSK	-0.6 ± 0.5	-1.0 ± 1.3	.046	NS
BUI	-1.1 ± 1.3	-1.0 ± 0.9	.800	NS
TUI	0.8 ± 0.9	-0.1 ± 0.6	<.001	**
TLI	0.2 ± 0.8	-0.1 ± 0.6	.066	NS
BLI	-1.1 ± 1.9	-1.4 ± 1.2	.493	NS
MNSK	2.9 ± 2.3	2.6 ± 1.6	.494	NS
OB	1.2 ± 1.3	-1.0 ± 1.7	<.001	**
Ga	-0.2 ± 3.6	-2.1 ± 4.6	.074	NS
SN-MPA	-0.5 ± 2.4	-1.0 ± 2.6	.334	NS
AFH	3.5 ± 2.3	3.6 ± 2.3	.706	NS

All measures are in millimeters except Ga and SN-MPA, which are in degrees

* Significant $P \leq .005$ between changes in treatment and changes in control groups
** Significant $P \leq .001$ between changes in treatment and changes in control groups

APPENDIX

IRB APPROVAL



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

ined 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.