Cephalometric evaluation of two treatment strategies for deep overbite correction

Mark G. Hans, DDS, MSD; Craig Kishiyama, DDS, MSD; Stephan H.Parker, DDS, MSD; Gary R. Wolf, DDS, MSD; Regine Noachtar, DDS

The difficulty of correcting deep overbite has been recognized for many decades. Through the years opinions have differed regarding the etiology of deep overbites and, consequently, how they should be treated. Moreover, facial type and/or facial type indicators (SN-MP, FMA, OM angle, mandibular arc, facial axis, and lower facial height) are thought to play a major role in predicting how an individual will respond to treatment.[1-3] A vertical discrepancy such as a deep bite can be studied from cephalometric measurements that evaluate vertical deviation from the norms, but it is not clear whether changes in these measures accurately translate into treatment response.

The first issue that must be addressed is how a deep overbite can be corrected. At present, this is not completely understood. Although there are many treatment modalities designed to specifically "open the bite", the relative contributions of tooth movement, skeletal change, and growth have not been fully studied. Four interrelated factors contribute to overbite correction: molar extrusion, incisor intrusion, tipping of the incisors and differential growth of maxillary and mandibular structures. These factors interact to produce the

Abstract

This study compared the cephalometric changes achieved using fixed versus removable appliances to correct deep overbite in growing patients. Forty-five patients treated with cervical headgear/tandem mechanics and 50 patients treated with a bionator appliance were compared with 95 control subjects from the Bolton Study. Treatment differences were determined using a cephalometric analysis that isolated vertical changes in overbite as the composite result of 6 variables: maxillary skeletal change, tipping of the upper incisors, bodily movement of the upper incisors, mandibular skeletal change, lower incisor tipping, and bodily movement of the lower incisors. The interaction of treatment type with facial type was also examined. In the headgear/tandem group, overbite was corrected by a combination of intrusion of the upper incisors and increases in mandibular skeletal change. Treatment with the bionator resulted in correction of the overbite by relative intrusion of the upper and lower incisors and increases in mandibular skeletal change. There were no significant interactions with facial type in the headgear group. Gonial angle and lower tipping were influenced by facial type in the bionator group. These results demonstrate that fixed and removable appliances produce both qualitative and quantitative differences in treatment response. Further studies are planned to create a rational decision tree that can be used to aid the clinician in the differential diagnosis and treatment of deep overbite.

Key Words

Cephalometric • Deepbite • Overbite

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Table I
Description Of Headgear/Tandem Sample

Treated Group

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

Age in years	Time 1	Time 2
Mean (s.d.)	10.3(1.8)	12.0(1.7)
Maximum	14.9	15.5
Minimum	7.3	8.8

Control Group

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

Age in Years	Time 1	Time 2
Mean(s.d)	10.4(1.8)	12.1(1.7)
Maximum	15.0	16.0
Minimum	7.0	9.0

N - Total Number of Male and Female

Table II
Description Of Bionator Sample

Treated Group

Facial Type	N	Male	Female
Euryprosopic	9	6	3
Mesoprosopic	30	16	14
Leptoprosopic	11	8	3

Age in Years	Time 1	Time 2
Mean (s.d.)	11.3 (1.6)	14.4 (1.7)
Maximum	14.4	18.5
Minimum	8.2	11.4

Control Group

Facial Type	N	Male	Female
Euryprosopic	7	4	3
Mesoprosopic	30	16	14
Leptoprosopic	11	8	3

Age in Years	Time 1	Time 2
Mean (s.d.)	11.2 (1.5)	14.4 (1.7)
Maximum	14.5	18.4
Minimum	8.0	12.0

N = Total Number of Male and Female

final "orthodontic result".[3,4]

Overbite correction has been observed and studied by regional superimposition and various cephalometric analyses. Superimpositional methods have been limited to qualitative results and individual amounts of tooth movement have not been reported. Cephalometric measurements have been developed by many investigators to evaluate amounts of intrusion or depression of the dental units. However, genuine intrusion and labial tipping movements were often not separated as different components, thus leading to possible faulty conclusions. Investigators who have recognized that tipping changes influence incisor vertical height have not yet devised a method to account for the interaction of these variables.[3,5-8]

Because of the importance of the vertical dimension in orthodontic treatment, an analysis was developed at Case Western Reserve University to study the interaction of tooth movement and skeletal growth for vertical changes during treatment.[9,10] This analysis was used in the present study to compare the correction of excessive overbite achieved using cervical pull headgear and tandem mechanics to the changes in overbite achieved using a bionator type appliance. In addition to these treatment modalities, facial type was also studied to assess its value as a predictor of treatment response.

Material and methods

Sample

This study examined the cephalometric records of 95 patients treated by orthodontists in private practice. Criteria for selection consisted of the availability of adequate pretreatment (T1) and post-bionator or post-cervical pull headgear/tandem cephalograms (T2) and the pretreatment condition of a deep overbite. Overbite was classified as deep when the lower incisal edge was beyond the cingulum of the maxillary incisor. This was determined cephalometrically, and if necessary, confirmed using pretreatment models.

The samples were separated into euryprosopic

Table III
Landmarks Used For Digitization

1.* Foramen rotundum in the pterygomaxillary fissure
2.* Three (3) mm above orbitale
3. Posterior Nasal Spine (PNS)
4. Anterior Nasal Spine (ANS)
5. Center of Resistance (CR) of the upper incisor
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)

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

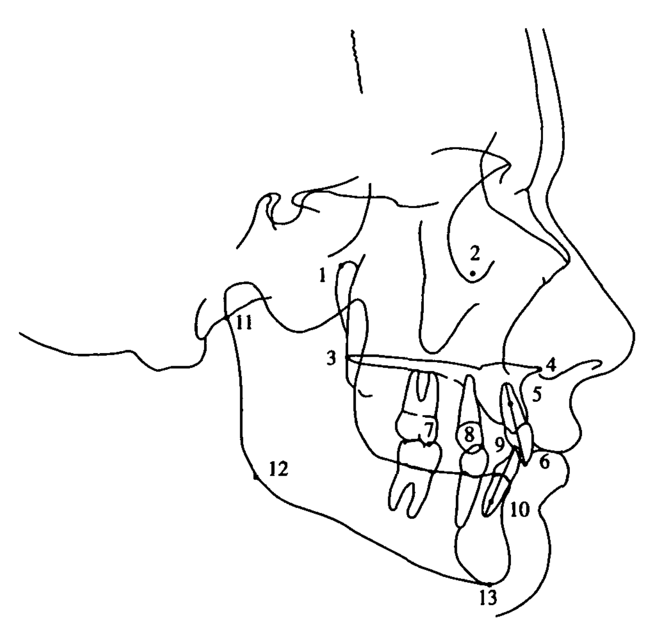

Figure 1

Figure 1
Points digitized

(wide and short), leptoprosopic (narrow and long), and mesoprosopic (intermediate) facial types using anthropometric values. The facial index was calculated using the skeletal length from Nasion to Menton (x 100) divided by bizygomatic breadth.[11] For patients who did not have a frontal cephalogram the clinical frontal and profile photographs (2-1/2" x 3-1/2") were used to measure the soft tissue facial index as described by Kishiyama.[11]

The control group consisted of 95 untreated deep overbite subjects from the Bolton Study (Case Western Reserve University, Cleveland, Ohio) who were classified by facial type in the same manner as the treatment group. All control cases had frontal and lateral headfilms available. Controls were selected to achieve a homogeneous sample with regard to gender, age, facial type and overbite (See Tables I, II). Separation based on Angle classification was not examined since Trouten[12] found no significant differences between Class I and Class II cases with deep overbite using Enlow's Counterpart Analysis.[13] Females over 14, and males over 18 years of age at the start of orthodontic treatment were excluded from the study because they were considered beyond significant growth years.[14]

Technical details

Sufficient anatomic structures were traced to allow identification of 13 registration points (See Figure 1 and Table III).

The two radiographs for each individual were labeled as follows:

T1 = Pretreatment film
T2 = Post-Cervical Headgear/Tandem or Post Bionator film
C1 = First control film
C2 = Second control film

All the landmarks were traced directly from T1 (or C1) and T2 (or C2) radiographs with the exception of the center of resistance (CR) for the upper and lower incisors and the fiducial reference plane. The CR for the incisors was arbitrarily set as 40% of the distance from the alveolar crest to the root apex. The CR point was transferred from time 1 to time 2 tracings using a template.[15] This distance was measured with a caliper (Helios) which is accurate to the nearest 0.1 mm and was marked on the long axis of each incisor at T1. The CR point was transferred to the T2 tracing by registration on the incisal edge.

Thirteen points were digitized (Table III) in sequence on a digitizing pad (Numonics Corporation, Montgomeryville, PA) which orients points based on an x-y coordinate system. (See Figure 1) The computer facilities used in this study are housed in the Bolton-Brush Growth Study Center at Case Western Reserve University (CWRU). Six linear measurements and two angular measurements were calculated using a commercially available software program (DentoFacial Planner 5.1, DentoFacial Software, Toronto, Canada).

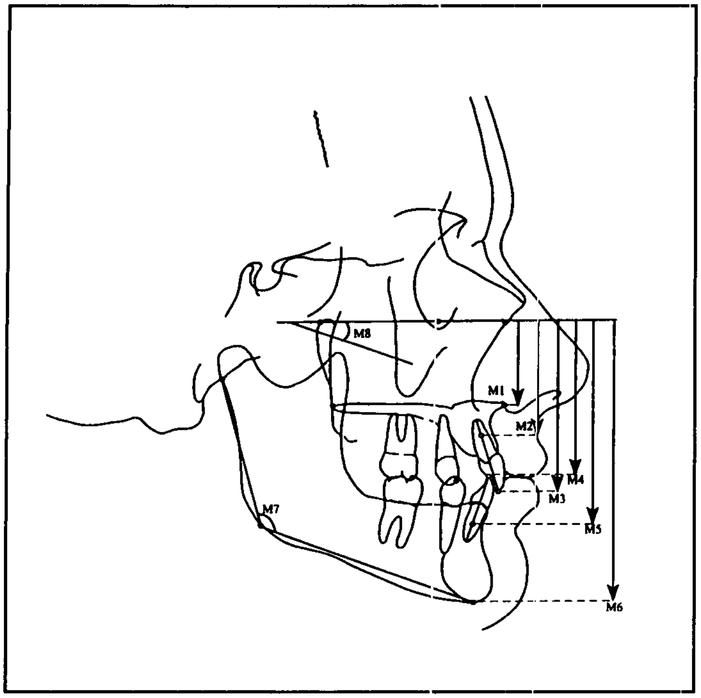

Figure 2

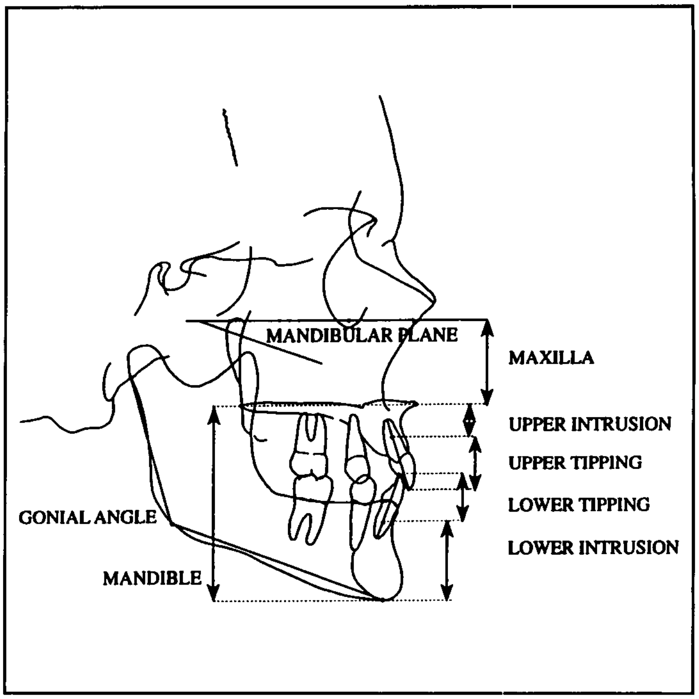

Figure 3

Figure 2
Anterior vertical analysis used in this study

Figure 3
Variables measured

Superimposition techniques

Two fiducial reference points were identified on the time 1 cephalogram (T_1 and C_1 respectively).[16] The time two cephalograms were superimposed on anterior cranial base landmarks after Bjork[17,18] and the two fiducial reference points transferred to the time 2 cephalograms (T_2,C_2 respectively).

Six linear measurements were taken to yield the six variables which form the basis of the analysis (see Figure 2). All linear measurements were measured perpendicular to the fiducial reference line.

Maxillary skeletal change (MAXILLA) is represented by the change in length from the reference line to ANS which is measurement one (M1). Bodily movement of the upper incisor (UPPER INTRUSION) evaluates the amount of extrusion or intrusion and is calculated by subtracting M1 from M2. Vertical change of the upper incisor due to tipping (UPPER TIPPING) is assessed by M3 - M2. Tipping (LOWER TIPPING) and bodily movement (LOWER INTRUSION) of the lower incisor are represented by M5 - M4 and M6 - M5, respectively. Mandibular skeletal change (MANDIBLE) is calculated by M6 - M1 while overbite (OVERBITE) is measured by M4 - M3. MANDIBLE includes all factors which influence the vertical position of the mandible. These factors include: 1) molar extrusion (which necessarily accompanies increased mandibular skeletal change); 2) changes in the mandibular plane angle; and 3) changes in gonial angle. Changes in the mandibular plane angle were compared at T_1 (C_1) and T_2 (C_2) by measuring the difference in the angle formed by the intersection of the fiducial reference line with the mandibular plane. The gonial angle was also measured since some authors have considered shape of the mandible to be more important than size in the deep overbite patient.[19,20]

Statistical methods

Data analysis was performed using the Statistical Package for the Social Sciences (SPSS-PC+) running on an IBM compatible personal computer (Digital One 486). Between-group (T_1-T_2 vs. C1-C_2) and within-group (T_1 vs. T_2, C_1 vs. C_2) differences were examined using t-tests. The effects of gender and facial type on treatment response were evaluated using multivariate ANOVA. A p-value of 0.05 was used to assign statistical significance.

Error study

Digitization error for each group was assessed by redigitizing the tracings of 5% of the patients. Intrainvestigator tracing error was assessed by retracing 10% of the patients chosen at random. The coefficient of linear correlation was calculated between the first and second determination for each dimension. The square of the coefficient, r_{xx}^2, estimates the reliability of each variable and is an estimate of "... the proportion of their variance that is true variance"[21]

Treatment methods

Bionator group: All patients were treated with a "deep bite" bionator or orthopedic corrector by private practitioners. (Drs. Mark G. Hans, Gary R.Wolf, Dennis DiPalma, Michael Sabat or Carl P. Dietrich) The appliance design included incisal capping, a coffin spring, a midline jackscrew and a Hawley type labial bow. All cephalometric records

Table IV
Descriptive Statistics
Headgear/Tandem Sample
Means and Standard Error of the Means Comparing Control and Treated Groups

	Control		Treated		T-test Betweem Treatment and Control Group
Variable	Mean	SEM	Mean	SEM	
MAXILLA	2.51+++	0.27	4.18 *++	0.35	***
UPPER INTRUSION	1.16+++	0.31	-0.72 ++	0.23	***
UPPER TIPPING	0.25NS	0.31	-0.01 NS	0.25	NS
OVERBITE	0.37NS	0.18	-4.86 +++	0.30	***
LOWER TIPPING	0.16NS	0.15	-0.71 +	0.28	**
LOWER INTRUSION	2.58+++	0.29	2.77 +++	0.34	NS
MANDIBLE	3.78+++	0.43	6.20 +++	0.46	***
GONIAL ANGLE	1.69++	0.39	-0.28 NS	0.35	**
MANDIBULAR PLANE	0.81++	0.29	-1.31 ++	0.31	***

all values in mm except GONIAL ANGLE and MANDIBULAR PLANE in degrees
* significant p<.05 between treatment and control groups
** significant p<.01 between treatment and control groups
*** significant p<.001 between treatment and control groups
\+ significant p≤.05 within treatment or within control groups
++ significant p≤.01 within treatment or within control groups
+++ significant p≤.001 within treatment or within control groups
NS not significant

were obtained before any fixed or removable appliances were used (T_1). The time 2 cephalogram (T_2) was taken after the bionator but before the placement of fixed appliances.

Tandem group: All patients were treated by one practitioner using treatment mechanics previously published (Dr. Andrew Haas, Cuyahoga Falls, Ohio).[22] To summarize, patients were treated using a cervical pull facebow and a 2x4 lever arch in the maxilla. The lever arch was cinched back and a gable bend was placed 1 mm anterior to the molar tube to intrude incisors. Bands were placed on all first molars, as well as the maxillary lateral and central incisors. A tandem yoke was used in the lower arch and inserted into round tubes on the first molars. The archwire was tied directly to the lower incisors with steel ligatures. Class III elastic traction was used along with the headgear to develop arch length in the mandible.

Results

Within-group changes for the Bionator and tandem treatment and control groups(C_1-C_2, T^1-T^2) are shown in Tables IV and V.

Within-group differences for both the control groups showed the same pattern of change. Quantitative differences between the two control groups are probably due to the difference in the time interval for the groups (1.69 years for the bionator group compared to 3.2 years for the tandem group).

One difference between the bionator and tandem within treatment group changes was that the gonial angle was unaffected in the tandem group while mandibular plane angle demonstrated a significant increase. Interestingly, the tandem group showed a significant increase in lower incisor tipping and no change in upper incisor angulation.

A comparison of the cephalometric measurements between treatment and control groups can be found in Tables IV and V.

Table V
Descriptive Statistics
Means and Standard Error of the Means Comparing Control and Treated Groups
Bionator Sample

	Control		Treated		T-test
Variable	Mean	SEM	Mean	SEM	P Value
MAXILLA	1.92 +++	1.46	2.39 +++	1.74	NS
UPPER INTRUSION	0.79 ++	0.90	-0.09 NS	1.10	***
UPPER TIPPING	0.05 NS	0.48	1.02 ++	0.96	***
OVERBITE	0.25 NS	1.06	-2.04 +++	2.08	***
LOWER TIPPING	0.14 NS	0.62	-0.33 NS	0.91	NS
LOWER INTRUSION	1.33 ++	1.25	0.80 +	1.19	**
MANDIBLE	1.79 ++	1.75	3.43 +++	1.94	***
GONIAL ANGLE	0.60 +	2.53	-1.38 ++	2.94	**
MANDIBULAR PLANE	+0.43 +	1.26	-0.27 NS	1.69	*

all values in mm except GONIAL ANGLE and MANDIBULAR PLANE in degrees
* significant $p<.05$
** significant $p<.01$
*** significant $p<.001$
NS not significant
\+ significant $p\leq.05$ within treatment or within control groups
++ significant $p\leq.01$ within treatment or within control groups

The use of cervical headgear and tandem mechanics resulted in significant changes between the treated and control groups for most of the variables tested. Only two dental variables, tipping of the upper incisor (UPPER TIPPING) and bodily movement of the lower incisor (LOWER INTRUSION) failed to reach significance (See Table IV). Three skeletal variables (MAXILLA, MANDIBLE, MANDIBULAR PLANE) showed highly significant differences ($p<.001$) between the treated and control group. In addition, the treated group experienced more bodily intrusion of the upper incisors than controls (UPPER INTRUSION =1.9 mm, $p\leq.001$).

Overbite decreased significantly ($p\leq.001$) in the treated group. On average, overbite was reduced nearly 5 mm. In contrast, overbite actually increased slightly in the control group. Overbite decreased an average of 2.3 mm. in all patients treated with the bionator appliance. All facial types exhibited a similar reduction.

Interactions with facial type

Facial type did not interact to magnify treatment response. However, when pretreatment and posttreatment values were compared to facial type in the bionator group, two variables had significance (LOWER INTRUSION $P\leq0.05$ and GONIAL ANGLE, $P\leq0.05$, see Table VI).

Discussion

The purpose of this study was to quantify overbite correction in such a way as to allow clinically relevant comparisons of different intervention strategies. Figures 4 and 5 graphically represent the comparison of these two treatment methods. All eight variables which interact to produce the observed change in overbite are shown. An arrow indicates the direction of change for all statistically significant between-group changes. Darker arrows represent a greater contribution. Movements contributing to a reduction in overbite were assigned a positive valve. Movements which increased vertical overbite were assigned negative valves.

Table VI
Descriptive Statistics
Means and Standard Error of the Means Comparing Facial Type with Treatment (in mm)
Bionator Sample

		Euryprosopic		Mesoprosopic		Leptoprosopic	
		Mean	SEM	Mean	SEM	Mean	SEM
MAXILLA	Control	+1.43	1.69	+2.00	1.17	+2.04	2.05
	Treatment	+2.14	2.11	+2.37	1.76	+2.56	1.63
UPPER INTRUSION	Control	+0.70	0.84	+0.85	0.87	+0.68	1.07
	Treatment	-0.14	0.96	-0.02	1.02	-0.23	1.53
UPPER TIPPING	Control	+0.13	0.52	+0.10	0.51	-0.11	0.36
	Treatment	+0.87	0.94	+1.10	1.01	+0.98	0.98
OVERBITE	Control	0.49	0.88	0.37	1.01	-0.24	1.22
	Treatment	-2.14	2.02	-1.98	2.13	-2.02	2.25
LOWER TIPPING	Control	+0.24	0.52	+0.12	0.49	+0.44	0.86
	Treatment	-0.48	1.13	-0.32	0.90	+0.29	0.91
LOWER INTRUSION	Control	+1.13	1.23	+1.20	1.06	+1.84	1.67
	Treatment	+0.60	1.06	+0.83	1.20	+0.94	1.37
MANDIBLE	Control	+1.71	1.24	+1.65	1.36	+2.21	2.79
	Treatment	+2.99	2.64	+3.57	1.50	+3.42	2.56
GONIAL ANGLE*	Control	+0.31	2.62	-0.58	2.69	-1.23	1.99
	Treatment	-1.87	2.20	+1.29	3.23	+1.35	3.10
MANDIBULAR* PLANE	Control	0.36	1.19	0.61	1.16	-0.02	1.53
	Treatment	-0.20	1.55	-0.28	1.42	-0.60	2.37

* in degrees

Our results indicate that fixed orthodontic therapy resulted in approximately twice as much correction of vertical overbite as removable appliances (5.2 mm compared to 2.3 mm) from T1 to T2. The magnitude of difference between the two methods was surprising. Three possible explanations are offered for this observation. First, our samples were not chosen based on treatment results. Patient compliance is known to be a critical factor for successful orthodontic treatment. Importantly, with removable appliance therapy, poor compliance results in no effective change from normal growth. Therefore, the response of the bionator group may have been affected by poor patient compliance to a greater degree than the tandem group. Second, it is possible that fixed appliances are simply more efficient for overbite correction. This explanation is also plausible, given that fixed appliances allow for direct application of force to teeth. Third, bionator patients were started into fixed appliances when the antero-posterior correction was completed. This correction may have occurred before complete overbite correction was achieved. Interestingly, both methods produced dental and skeletal changes, contradicting claims that fixed appliances only move teeth and only removable appliances can modify skeletal growth.

The results of the tandem mechanics sample demonstrate that this mechanical system increases the vertical height of both the maxilla and the mandible. This would suggest that patients with decreased lower vertical facial height would derive the greatest esthetic benefit from this technique. Our data support the classic argument that mandibular plane angle is increased with cervical traction. In contrast to the tandem group, the bionator sample showed only about one-third of the amount of increase in MANDIBULAR PLANE compared to the cervical headgear sample. Both samples demonstrated net increases in the gonial angle (headgear/tandem= 1.4°, bionator = 2°) and in the bionator group gonial angle showed an absolute increase of

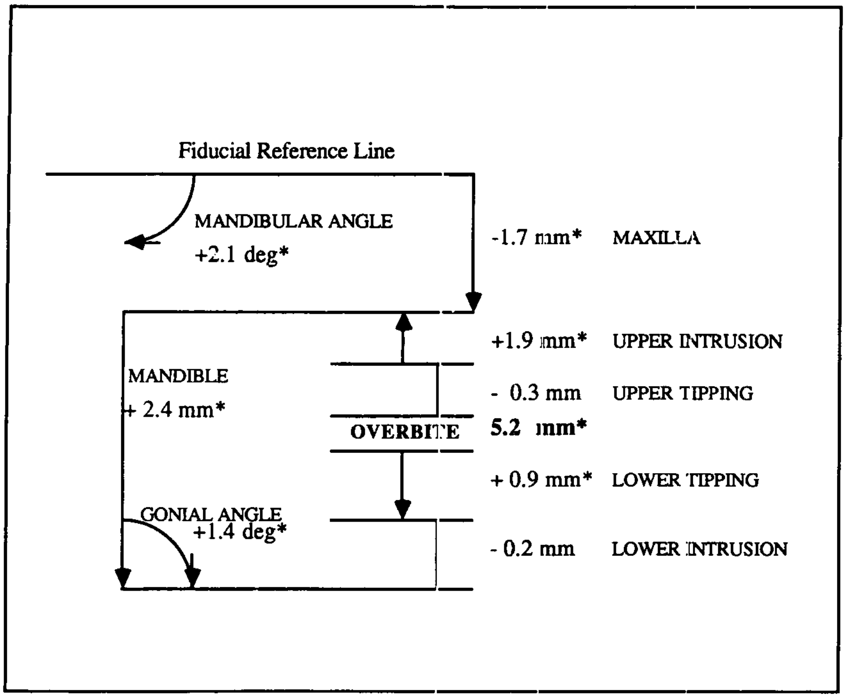

Figure 4
Cervical headgear/ tandem mechanics sample

1.4° with treatment.

Our data did not support the common belief that bionators procline the lower incisors excessively. In fact, in the leptoprosopic group the lower incisor actually moved lingually with treatment. This finding suggests that vertical growth of the face, and especially mandibular vertical change, can affect final tooth position.

Johnston's finding that "things go better with growth" is certainly supported by our data.[23] In fact, about 50% of the change in overbite in the fixed appliance group (MANDIBLE = 2.4 mm/OVERBITE = 5.2 mm) and 100% of the change in overbite in the bionator groups (UPPER INTRUSION = .9 mm. + MANDIBLE 1.6,/OVERBITE 2.3 mm) was directly related to changes in vertical growth of the face. This finding is further support for the contention that orthodontic treatment interventions act synergistically with growth by modifying dental and skeletal structures. The dental changes found in the bionator group would probably not have occurred to the same degree in the nongrowing patient. Therefore, fixed appliance therapy is probably the most effective treatment modality to correct deep overbite for a patient that is beyond significant growth years.

Improvement in the vertical position of the upper incisors with respect to the maxillary apical base was seen with both treatment methods. This finding supports the clinical observation that improvement in smile line and anterior dental esthetics can be achieved by both treatment modalities. However, the fixed lever arch was more effective for intruding upper incisors.

The results presented in these studies are subject to some limitations. First, all tandem cases were treated by one clinician. This may be a source of experimental bias. It is possible that this clinician had a higher level of patient compliance than the clinicians using the removable appliances. Therefore, the results may in part reflect the operator's ability rather than the appliance's efficiency. Second, removable appliances, by their nature, are more susceptible to variations in patient compliance. Therefore, quantitative differences in effect may reflect variations in compliance rather than variations in mechanical response. This limitation would seem to be inherent in removable appliance therapy and, therefore, may not affect the validity of using our data to make clinical decisions on appliance choice. Third, although the difference in treatment times between the bionator and tandem groups were minimized by matching controls on age and gender, it is possible that some of the quantitative differences between treatment modalities were due to treatment time and not solely to treatment method. Fourth, subdividing the samples by facial type might have reduced the sample size below the level necessary to detect differences related to facial type. Further studies are planned with increased sample sizes to more definitively examine the effect of facial type on treatment response. Finally, only two of the many possible treatment techniques for correction of deep bite were examined.

Summary and conclusions

Both types of treatment studied, tandem mechanics and bionator therapy, successfully corrected the pretreatment condition of deep overbite. The difference was both statistically and clinically significant. In short, both treatments work. Fixed appliances, by design, are more efficient in moving teeth and in this study they provided twice as much vertical change in overbite.

Both appliances produced similar dental and skeletal changes. The most striking qualitative difference between them was that the bionator response was affected by facial type and the tandem response was not. In addition, the tandem results produced, on average, longer faces than the bionator group. This may or may not be a desirable treatment result depending on the individual patient's facial morphology.

The results reported in this article should provide the clinician with more information on patient response to therapy than has been previously available. It is hoped that clinicians can use this information to improve the quality of the orthodontic services they provide.

Although many criteria can and should be used by the astute clinician in planning orthodontic therapy, the decision on the mode of treatment to be used for correction of deep overbite can at least in part be based on the following observations:

1. Tandem mechanics maximize upper incisor intrusion. This is at the expense of increases in maxillary vertical growth.
2. Tandem mechanics produce the greatest amount of mandibular vertical change with the largest increase in the mandibular plane angle.
3. Bionators/orthopedic correctors produce about two-thirds of the increase in mandibular skeletal height seen in the tandem group with about one-third of the change in mandibular plane angle.
4. Bionators/orthopedic correctors produce almost half of their net effect by inhibiting the normal eruption of the upper incisor that occurs with growth.

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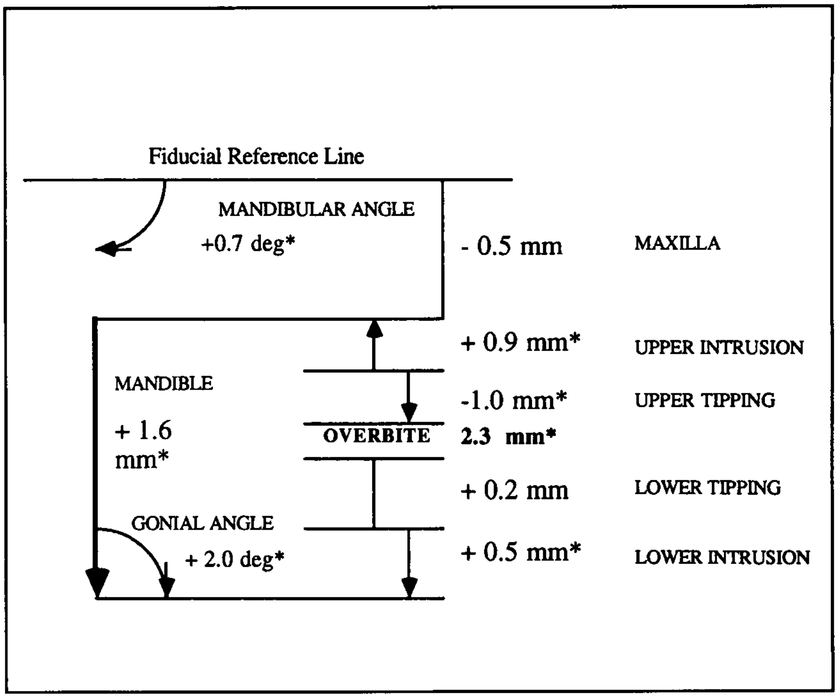

Figure 5

Author Address

Mark G. Hans, DDS, MSD
Department of Orthodontics
Case Western Reserve University
School of Dentistry
10900 Euclid Ave.
Cleveland, Ohio 44106-4905

M.G. Hans, Assistant Professor and Graduate Program Director, Case Western Reserve University.

C. Kishiyama is an orthodontist in private practice in Anaheim, Calif.

S.H. Parker, Assistant Clinical Professor, Department of Orthodontics, Case Western Reserve University, Cleveland, Ohio.

G.R. Wolf, Assistant Clinical Professor, Department of Orthodontics, Case Western Reserve University, Cleveland, Ohio.

R. Noachtar, Research Associate, Bolton-Brush Growth Study Center, Case Western Reserve University, Cleveland, Ohio.

Figure 5
Bionator sample

References

1. Schudy FF. The control of vertical overbite in clinical orthodontics. Angle Orthod 1968;38:19-39.
2. Bench RW, Gugino CF, Hilgers JJ. Bioprogressive Therapy: Part 4. J Clin Orthod 1977;11:820-834..
3. Engel G, et al. Treatment of deep-bite cases. Am J Orthod 1980;77:1-13.
4. Simons ME, Joondeph DR. Change in overbite: a ten-year post-retention study. Am J Orthod 1973;64:349-367.
5. Castaldo DA. *A roentgenographic cephalometric appraisal of the tooth movements contributing to overbite correction in treatments utilizing an anterior high-pull headgear*. Fairleigh Dickinson University; 1970. Thesis
6. Barton KA. Overbite changes in the Begg and edgewise techniques. Am J Orthod 1972;62:48-55.
7. Carlyle TD. *Overbite: craniofacial associations, treatment and posttreatment changes: a lateral cephalometric study*. Winnipeg, Manitoba: University of Manitoba, 1977. Thesis.
8. Otto RL, Anholm JM, Engle GA. A comparative analysis of intrusion of incisor teeth achieved in adults and children according to facial type. Am J Orthod. 1980;79:437-446.
9. Kishiyama CA. *An evaluation of response to orthodontic treatment of deep overbite in Eury-, Meso-, and Leptoprosopic individuals.* Cleveland, Ohio: Case Western Reserve University. 1987. Thesis.
10. Parker SH. *Cephalometric evaluation of response to orthodontic treatment of deep overbite with cervical pull facebow headgear in Eury-, Meso-, and Leptoprosopic individuals.* Cleveland, Ohio: Case Western Reserve University. 1988. Thesis.
11. Montague MFA. A Handbook of Anthropometry. Charles C. Thomas, Springfield, Illinois. 1960.
12. Trouten JC. *Analysis of skeletal open bite and deep bite utilizing the counterpart analysis.* Cleveland, Ohio: Case Western Reserve University. 1980.
13. Enlow DH. Handbook of Facial Growth. WB. Saunders CO. Philadelphia. 1982.
14. Broadbent BH, Sr., Broadbent BH Jr, Golden WH. Bolton Standards of Dentofacial Developmental Growth. CV. Mosby Co. 1975.
15. Liu SY, Herschleb CW. Controlled movement of maxillary incisors in the Begg technique. Am J Orthod 1981;80:300-315.
16. Baumrind S, Miller DM. Computer aided head film analysis: The University of California San Francisco method. Am J Orthod. 1980;78:41-65.
17. Björk A. Cranial Base Development. Am J Orthod. 1955;41:198-225.
18. Björk A. Facial growth in man, studied with the aid of metallic implants. Acta Odont Scan. 1955;13:9-34.
19. Richardson A. Skeletal factors in anterior open-bite and deep overbite. Am J Orthod. 1969;56:114-127..
20. Moss ML, Salentijn L. Differences between the functional matrices in anterior open-bite and in deep overbite. Am J Orthod. 1971;60:264-280.
21. Guilford JP. Fundamental Statistics in Psychology and Education. McGraw-Hill, Inc. New York. 1971.
22. Renfroe EW. Edgewise. Lea & Febiger 1975. Philadelphia pp 173-174, 469.
23. Johnston LE. A Comparative Analysis of Class II Treatments. In: Science and Clinical Judgement in Orthodontics. Monograph #19, Craniofacial Growth Series, Center for Human Growth & Development, University of Michigan, Ann Arbor, 1986.