ORIGINAL ARTICLE

Treatment effects of the bionator and high-pull facebow combination followed by fixed appliances in patients with increased vertical dimensions

Christopher S. Freeman,[a] James A. McNamara, Jr,[b] Tiziano Baccetti,[c] Lorenzo Franchi,[d] and Theodore W. Graff[e]

Ann Arbor, Mich, Fort Lauderdale, Fla, Florence, Italy, and Endicott, NY

Introduction: The purpose of this study was to evaluate the effectiveness of a first phase of bionator and high-pull facebow treatment followed by a second phase of fixed appliance therapy in growing subjects with increased vertical dimensions. **Methods:** The records of 24 subjects with high-angle skeletal relationships (mean MPA value ~30°) treated consecutively with this protocol were examined. Cephalometric measurements were compared with those obtained from 23 sets of records of an untreated group matched according to age, gender, vertical skeletal relationships, and time intervals between records. The matched group of patients was from the University of Michigan Elementary and Secondary School Growth Study. Lateral cephalograms were analyzed prior to the start of treatment (T1, mean age 9.1 years), at the start of phase 2 treatment (T2, mean age 11.9 years), and after phase 2 treatment (T3, mean age 14.7 years). The total treatment duration (phase 1, retention, and phase 2) for the treated group was 5.5 years, whereas the control group total time interval averaged 5.6 years. **Results:** As to sagittal relationships, no significant differences were found between treated subjects and controls at the end of the 2-phase treatment for all measurements. Counterintuitively, the bionator and high-pull headgear combination worsened the hyperdivergent facial pattern at a clinically significant level, as shown by analysis of final facial forms. The treated group exhibited a significantly larger MPA value than controls (2.5°) as well as a larger inclination of the Frankfort horizontal to the occlusal plane (2.8°). **Conclusions:** Based on the analysis of this sample, the examined therapeutic protocol does not appear to be a recommendable option for treatment of subjects with increased vertical dimensions. (Am J Orthod Dentofacial Orthop 2007;131:184-95)

The most common maxillary characteristics of patients with hyperdivergent facial patterns are excessive maxillary anterior and posterior dentoalveolar heights and flat palatal plane angles; their mandibular characteristics are excessive mandibular dentoalveolar heights, increased lower anterior facial heights, steep mandibular plane angles, and short ramus heights, leading to retrusive positions of the mandible.[1-3] When treating a growing patient with a hyperdivergent facial pattern, orthodontic/orthopedic intervention is aimed to achieve 3 fundamental goals with regard to the vertical development of the face and dentition: to rotate the maxilla in a clockwise direction; to inhibit maxillary and mandibular posterior dental eruption, allowing the mandible to rotate counterclockwise; and to guide mandibular growth in an anterior rather than a vertical direction.

Of the many protocols that have been suggested for the treatment of hyperdivergent patients (conventional fixed appliances combined with extractions,[4] posterior bite blocks with and without repelling magnets,[5,6] bonded acrylic splint expanders,[7] vertical-pull chincups,[8,9] high-pull facebows,[10] and functional jaw orthopedics[11]), a modality that at least theoretically could accomplish all of these goals simultaneously is a bionator used with a high-pull facebow in growing

[a]Graduate Orthodontic Program, University of Michigan, Ann Arbor, Mich; private practice, Fort Lauderdale, Fla.
[b]Thomas M. and Doris Graber Endowed Professor of Dentistry, Department of Orthodontics and Pediatric Dentistry, School of Dentistry; professor of Cell and Developmental Biology, School of Medicine; research professor, Center for Human Growth and Development, University of Michigan; private practice, Ann Arbor, Mich.
[c]Assistant professor, Department of Orthodontics, University of Florence, Florence, Italy; Thomas M. Graber Visiting Scholar, Department of Orthodontics and Pediatric Dentistry, School of Dentistry, University of Michigan, Ann Arbor, Mich.
[d]Research professor, Department of Orthodontics, University of Florence, Florence, Italy; Thomas M. Graber Visiting Scholar, Department of Orthodontics and Pediatric Dentistry, School of Dentistry, University of Michigan, Ann Arbor, Mich.
[e]Private practice, Endicott, NY.
Supported in part by funds made available through the Thomas M. and Doris Graber Endowed Professorship, School of Dentistry, University of Michigan.
Reprint requests to: Dr James A. McNamara, Department of Orthodontics and Pediatric Dentistry, University of Michigan, Ann Arbor, MI 48109-1078; e-mail, mcnamara@umich.edu.
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patients. Presumably, the high-pull facebow would help to rotate the maxilla in a clockwise direction and inhibit the eruption of the maxillary posterior dentition. At the same time, the acrylic of the bionator that is positioned between the maxillary and mandibular posterior teeth (assuming that it is thicker than the freeway space) would further inhibit posterior dental vertical development. Also, the lingual flanges of the bionator would cause the patient to posture the mandible in a forward position (if desired) in an attempt to generate a more anterior direction of growth secondary to altered mandibular function.

To date, the literature lacks information about the effects of the bionator combined with high-pull headgear in patients with increased vertical dimensions. Only a few studies have evaluated the results of a headgear-activator combination; some discussed the vertical effects accompanying this type of treatment. Headgear-activator combination appliances produced favorable effects in treated patients because the therapy prevented the vertical relationships and the inclination of the occlusal plane from increasing.[11-17] The addition of a headgear to functional appliance treatment appears to yield an outcome that is desirable in high-angle patients.

When bionator therapy alone was considered, Lange et al,[18] Morris et al,[19] and Illing et al[20] reported significant increases in lower anterior facial height during treatment, an undesirable treatment effect in this type of patient. Faltin et al[21] found a significant opening of the gonial angle in treated subjects compared with untreated controls.

Most studies on the headgear-activator combination and the bionator alone did not include untreated controls for the evaluation of treatment effectiveness,[13-16] and they did not provide specific information about the pretreatment vertical skeletal patterns of the subjects.

Our purpose in this clinical investigation was to make a detailed comparison between patients with increased vertical dimensions who underwent 2-phase treatment consisting of a first phase with a bionator and high-pull facebow combination followed by a second phase of fixed appliances and a matched sample of untreated subjects with the same craniofacial morphology followed longitudinally.

PATIENTS AND METHODS

The bionator high-pull facebow sample was derived from a group of 40 consecutively treated patients from the private orthodontic practice of an author (T.W.G.). Treatment results were not a criterion for case selection.

To be included in this study, patients were required to meet the following criteria: (1) 2-phase treatment consisting of bionator and high-pull facebow wear followed by preadjusted edgewise orthodontic treatment; (2) pretreatment Angle Class I or Class II malocclusion; (3) 3 high-quality lateral cephalograms in centric occlusion with adequate visualization of reference structures and no appreciable rotation of the head, obtained before phase 1 treatment (T1), before phase 2 treatment (T2), and after phase 2 treatment (T3); and (4) as derived from the cephalometric analysis at T1, value for the mandibular plane relative to the Frankfort horizontal (MPA) of 25° or greater.

Twenty-four (13 girls, 11 boys) of the 40 subjects met the inclusionary criteria. The treated group comprised 15 subjects with end-to-end molar relationship, 5 with full Class II molar relationships, and 4 with Class I molar relationships. The average ages were 9.2 years for the bionator and high-pull facebow group at T1, 12.6 years at T2, and 14.7 years at T3.

Cephalograms representing T1, T2, and T3 were selected for 23 subjects (10 girls, 13 boys) with hyperdivergent facial patterns (MPA $>25°$) from the archives of the University of Michigan Elementary and Secondary School Growth Study. The control group consisted of 15 subjects with end-to-end molar relationships, 3 with full Class II molar relationships, and 5 with Class I molar relationships; this distribution in molar relationships was similar to the treated sample. The subjects were similar to those of the treated group in age at all observation times, duration of observation intervals, gender, and MPA. The average ages were 9.1 years at T1, 11.9 years at T2, and 14.7 years at T3.

Treatment protocol

For phase 1, the bionator was constructed with a 4 to 5 mm posterior bite block that extended anteriorly to the deciduous first molars (Fig 1). Ball clasps for retention were included in the permanent maxillary first molar region. Headgear tubes (.045 in) were embedded at the level of the permanent first molars. A tongue shield to prevent tongue thrust was included with appropriate air holes. A maxillary holding frame (Hawley design) with adjustable loops also was incorporated. If mandibular retrusion was part of the skeletal configuration, up to a 4-mm advancement was incorporated into the construction bite.

The patients were instructed to wear the bionator full time except for meals. High-pull headgear also was worn for 10 to 14 hours a day (Fig 1). The anticipated phase 1 treatment time was 8 to 12 months on this regimen; however, level of cooperation and treatment outcome sometimes extended the treatment time.

In phase 2, the main purpose was to refine the

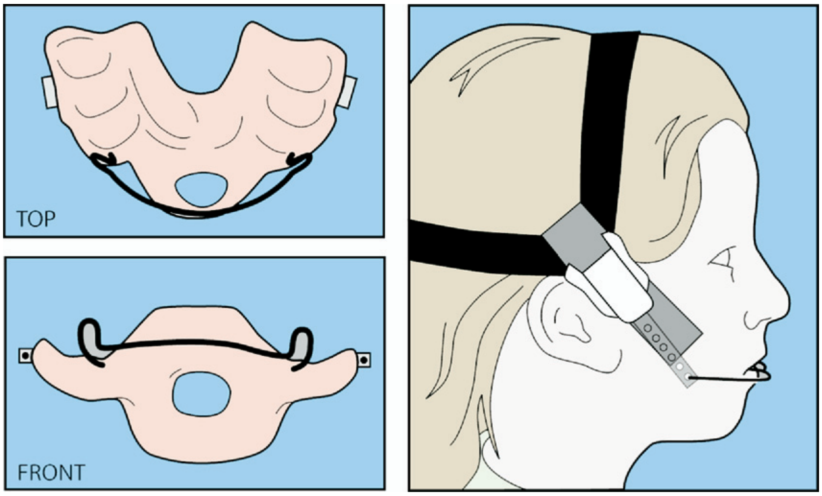

Fig 1. Bionator with high-pull facebow.

occlusion; it consisted of complete banding/bonding with 0.018-in slot preadjusted fixed appliances. Class II mechanics such as elastics were used as necessary, and the wearing of the high-pull facebow was continued.

Cephalometric analysis

The T1, T2, and T3 cephalograms were hand-traced on 0.003-in frosted acetate with a 2H sharpened lead drafting pencil. Films of a given series were traced at 1 sitting in the same manner by 1 investigator (C.S.F.) and then verified for anatomical contour and landmark identification as well as tracing superimpositions by a second investigator (J.A.Mc.). Cephalometric software (Dentofacial Planner, version 2.5, Toronto, Ontario, Canada) was used for a customized digitization regimen that included 78 landmarks and 4 fiducial markers. This program allowed for analysis of cephalometric data and superimposition of serial cephalograms according to the specific needs of this study.

Lateral cephalograms for each patient at T1, T2, and T3 were digitized, and 50 variables were generated for each film. The magnification factor of the cephalograms was standardized at 8%. A cephalometric and regional superimposition analysis containing measurements chosen from the analyses of McNamara,[22-24] Ricketts,[25] and Steiner,[26] and the Wits appraisal[27] was performed on each cephalogram analyzed in the study.

The cranial base superimpositions were performed by aligning the basion-nasion line and registering at the most posterosuperior aspect of the pterygomaxillary fissure.[22,25] In addition, the posterior cranial outline was used to verify the superimposition of cranial base structures. From this superimposition, position changes of the maxilla and mandible were measured. To superimpose the maxilla along the palatal plane, the superior and inferior surfaces of the hard palate and internal structures of the maxilla superior to the incisors were used as landmarks. From this superimposition, the movements of the maxillary incisors and molars could be assessed. The mandibular superimposition was performed by using the mandibular canal posteriorly, the internal structures of the symphysis, and the posterior contour of the symphyseal outline. This superimposition allowed the measurement of movement of the mandibular teeth in the mandible.

Cervical vertebral maturation analysis

The subjects in both groups were analyzed at T1, T2, and T3 with a reliable method for the assessment of skeletal maturity, the recently improved version of the cervical vertebral maturation (CVM) method.[28]

Statistical analysis

Means and standard deviations for age, duration of treatment, and all cephalometric measurements at T1, T2, and T3 for the bionator and high-pull facebow and the untreated control groups were calculated. Additionally, mean differences and standard deviations were calculated for the changes of T2-T1, T3-T2, and T3-T1 for each group. The data were analyzed with statistical software (12.0, SPSS, Chicago, Ill). Statistical significance was tested at $P < .05$, $P < .01$, and $P < .001$ levels. The method error was described previously by McNamara et al.[24]

An exploratory Shapiro-Wilks test was performed

Table I. Comparison of starting forms at T1

	Bionator + facebow (n = 24)		Controls (n = 23)			
Cephalometric measurements	*Mean*	*SD*	*Mean*	*SD*	*Difference*	*Significance*
Maxillary skeletal						
SNA angle (°)	81.2	4.1	80.4	3.8	0.8	NS
Pt A to nasion perp (mm)	0.5	2.8	−0.3	2.9	0.8	NS
Co-Pt A (mm)	82.8	4.5	80.6	4.7	2.2	NS
Mandibular skeletal						
SNB angle (°)	75.1	3.8	75.3	3.1	−0.2	NS
Pog to nasion perp (mm)	−9.3	5.4	−8.3	4.2	−1.0	NS
Co-Gn (mm)	100.9	5.1	98.8	5.4	2.1	NS
Maxillary/mandibular						
ANB angle (°)	6.1	2.6	5.1	1.9	1.0	NS
Wits (mm)	1.7	3.2	0.9	2.4	0.8	NS
Maxillary/mandibular difference (mm)	18.2	3.4	18.2	2.0	0.0	NS
Vertical skeletal						
MPA (°)	30.1	4.5	29.4	3.0	0.7	NS
ANS to Me (mm) LAFH	62.7	6.2	60.5	4.3	2.2	NS
Ar-Go (mm)	36.1	3.1	35.2	3.2	0.9	NS
N-Me (mm) AFH	106.5	7.3	103.7	4.9	2.8	NS
Co-Go (mm)	43.2	3.7	39.7	3.2	3.5	*
Gonial angle (°)	131.7	6.0	131.7	4.7	0.0	NS
FH to occlusal plane (°)	11.5	3.0	11.2	2.4	0.3	NS
FH to palatal plane (°)	1.9	3.4	1.5	2.6	0.4	NS
Interdental						
Overbite (mm)	1.3	3.2	0.9	3.2	0.4	NS
Overjet (mm)	5.8	1.9	5.0	1.9	0.8	NS
Interincisal angle (°)	122.9	9.2	122.0	8.3	0.9	NS
Molar relationship (mm)	−0.3	1.5	0.4	1.1	−0.7	NS
Maxillary dentoalveolar						
U1 to Pt A vert (mm)	4.1	1.9	4.0	1.6	0.1	NS
Mandibular dentoalveolar						
L1 to Pt A Pog (mm)	1.6	1.7	1.6	2.1	0.0	NS
L1 to MP (°)	94.0	6.7	95.9	4.4	−1.9	NS
Soft tissue						
UL to E plane (mm)	−0.8	2.2	−1.3	2.2	0.5	NS
LL to E plane (mm)	0.9	2.0	0.1	1.9	0.8	NS
Nasolabial angle (°)	112.9	12.5	113.4	8.9	−0.5	NS

*$P < .05$; *NS,* not significant.

on all variables to test the normality of the sample. The results were not significant; this indicated normality of distribution for the examined parameters and recommended parametric statistics. Starting and final forms in the 2 groups were compared with independent sample *t* tests. Mean differences between the treatment and control groups at the different time intervals (T2-T1, T3-T2, and T3-T1) were compared by using independent sample *t* tests as well. The analysis of power of the study indicated that, on the basis of number of subjects in the examined groups and the standard deviations of the cephalometric variables, the level of clinical significance for treatment-induced differences with regard to vertical dimension change was equal or greater than 2 mm or 2° for a power of 0.80.

RESULTS

Analysis of starting forms

Descriptive statistics including means and standard deviations for both groups at the start of treatment are given in Table I. Significant between-group differences were noted for only 1 measurement. The treatment group initially had greater mandibular ramus height (Co-Go). The mean value of the MPA for both groups was about 30° (range, 25.6° to 39.1°).

Analysis of T1-T2 changes

There were no significant differences in the skeletal changes between the 2 groups for any maxillary measurement in the sagittal plane from T1

Table II. Comparison of changes during phase 1 treatment (T1 to T2)

Cephalometric measurements	*Bionator + facebow (n = 24)*		*Controls (n = 23)*			
	Mean	*SD*	*Mean*	*SD*	*Difference*	*Significance*
Maxillary skeletal						
SNA angle (°)	−0.3	2.0	−0.4	1.4	0.1	NS
Pt A to nasion perp (mm)	−0.5	1.7	−0.4	1.2	−0.1	NS
Co-Pt A (mm)	3.3	1.9	3.3	1.9	0.0	NS
Mandibular skeletal						
SNB angle (°)	0.9	1.7	0.2	1.2	0.7	NS
Pog to nasion perp (mm)	1.2	2.7	0.2	1.8	1.0	NS
Co-Gn (mm)	7.6	3.4	5.4	2.5	2.2	*
Maxillary/mandibular						
ANB angle (°)	−1.3	1.7	−0.5	0.9	−0.8	NS
Wits (mm)	−0.8	2.6	0.0	1.6	−0.8	NS
Maxillary/mandibular difference (mm)	4.3	2.7	2.1	1.7	2.2	†
Vertical skeletal						
MPA (°)	0.3	1.5	−0.3	1.4	0.6	NS
ANS to Me (mm) LAFH	3.5	2.1	2.2	1.7	1.3	*
Ar-Go (mm)	3.1	2.3	2.0	1.5	1.1	NS
N-Me (mm) AFH	8.0	3.8	5.9	3.0	2.1	*
Co-Go (mm)	3.1	3.3	2.4	2.3	1.7	NS
Gonial angle (°)	−1.3	2.7	−1.6	2.1	0.3	NS
FH to occlusal plane (°)	−1.7	2.6	−1.6	3.0	−0.1	NS
FH to palatal plane (°)	−1.9	2.1	−1.0	1.7	−0.9	NS
Interdental						
Overbite (mm)	1.0	2.7	1.2	2.0	−0.2	NS
Overjet (mm)	−1.0	1.7	−0.1	1.0	−0.9	*
Interincisal angle (°)	4.2	8.3	1.4	6.1	2.8	NS
Molar relationship (mm)	2.0	1.8	0.5	1.0	1.5	†
Maxillary dentoalveolar						
U1 to Pt A vert (mm)	0.2	1.5	0.6	1.0	−0.4	NS
U1 horizontal (mm)	0.1	1.7	0.5	1.3	−0.4	NS
U1 vertical (mm)	1.8	1.6	1.8	1.6	0.0	NS
U6 horizontal (mm)	0.3	1.9	0.7	1.1	−0.4	NS
U6 vertical (mm)	0.7	1.7	0.6	1.3	0.1	NS
Mandibular dentoalveolar						
L1 to Pt A Pog (mm)	0.3	1.2	0.5	1.1	−0.2	NS
L1 horizontal (mm)	0.0	1.3	0.6	1.1	−0.6	NS
L1 vertical (mm)	2.8	2.0	1.9	1.1	0.9	NS
L6 horizontal (mm)	1.6	1.5	1.5	1.1	0.1	NS
L6 vertical (mm)	2.6	1.6	1.6	1.3	1.0	*
L1 to MP (°)	−3.4	4.6	0.3	3.4	−3.7	†
Soft tissue						
UL to E plane (mm)	−2.1	2.1	−1.7	1.3	−0.4	NS
LL to E plane (mm)	−1.0	1.8	−0.3	1.4	−0.7	NS
Nasolabial angle (°)	3.3	9.5	3.8	6.7	−0.5	NS

*$P < .05$; †$P < .01$; *NS,* not significant.

to T2 (Table II, Figs 2 and 3). Total mandibular length (Co-Gn) showed a significantly larger increase in the treated group than in the control group (2.2 mm). No other significant changes were found. From T1 to T2, the treated group had significantly greater increases in maxillary/mandibular differential compared with the control group (2.2 mm). The changes in the Wits appraisal and the ANB angle were not significantly different between the 2 groups.

Significantly greater differences were found for the increase in lower anterior facial height (ANS-Me) in the treated group compared with the control group (1.3 mm). Similarly, the increase in total anterior facial height (N-Me) was significantly greater in the treated group when compared with the control group (2.1 mm).

There was a significantly larger decrease in overjet in the treated group compared with the control group (−0.9 mm). Molar relationship had a greater increase in

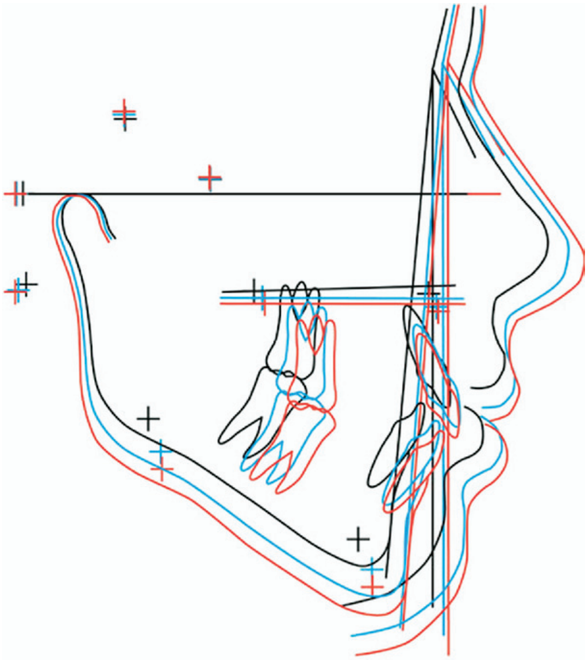

Fig 2. Composite tracings of treated group at T1 (black), T2 (*blue*), and T3 (*red*).

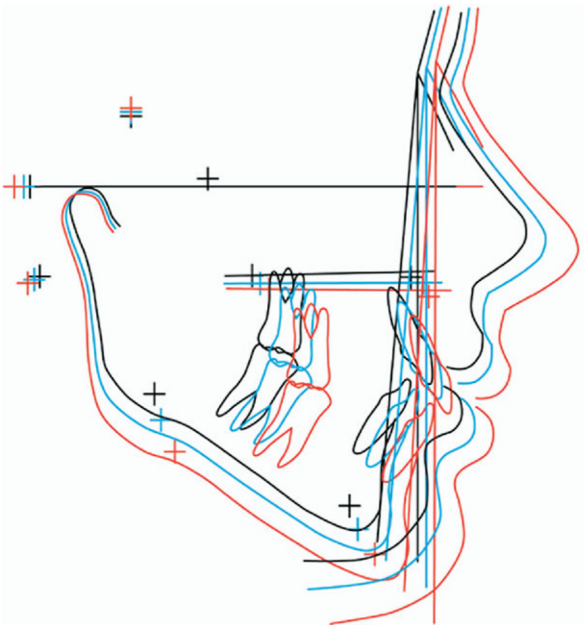

Fig 3. Composite tracings of control group at T1 (*black*), T2 (*blue*), and T3 (*red*).

the treated group than the untreated group (1.5 mm). No significant differences were found between the 2 groups for the T1 to T2 changes. A significantly larger increase in the vertical position of the mandibular first molar (L6 vertical) was recorded in the treated group when compared with the untreated controls (1.0 mm). A significant amount of lingual tipping of the mandibular incisor occurred in the treated sample (−3.7°).

No significant soft-tissue differences were found for the T1-T2 changes between the 2 groups.

Analysis of T2-T3 changes

There were significant differences between the 2 groups for all maxillary skeletal measurements in the sagittal plane from T2 to T3 (Table III, Figs 2 and 3). Both SNA angle and Point A to nasion perpendicular showed significant decreases in the treated group when compared with the increases in the untreated controls (approximately −1.0° and −1 mm, respectively). Midfacial length showed significantly smaller increases in the treated group (−1.9 mm). There were significant differences between the 2 groups for all mandibular measurements in the sagittal plane from T2 to T3. Both SNB angle and pogonion to nasion perpendicular had significant decreases in the treated group when compared with the increases in the untreated controls (−1.4° and −2.7 mm, respectively). Total mandibular length showed significantly smaller increases in the treated group (−3.9 mm). During phase 2 (T2 to T3), the treated group had significantly smaller increases in maxillary/mandibular differential compared with the control group (−2.0 mm). The changes in the Wits appraisal and the ANB angle were not significantly different in the 2 groups.

A significant increase in MPA was noted in the treated group with respect to the decrease seen in the controls (1.3°). Significantly smaller increases were found for both ramus height (Ar-Go) and total anterior facial height (N-Me) in the treated group compared with the control group (−1.3 and −2.7 mm, respectively). A significant increase in inclination of Frankfort horizontal to occlusal plane occurred in the treated group compared with the decrease in the controls.

The only dental measurement with a significant difference between the treated and the control groups was interincisal angle, with a significant decrease in the treated group compared with the controls (−8.3°). No significant differences were found between the 2 groups for the T2 to T3 changes. A significant increase in the sagittal position of the mandibular incisor (L1 to Pt A Pog and L1 horizontal) was recorded in the treated group when compared with the decreases in the untreated controls (1.8 and 1.3 mm, respectively). A significantly smaller extrusion of the mandibular incisor (L1 vertical) occurred in the treated sample (−1.1 mm). A significant flaring of the mandibular incisor (L1 to MP) was observed in the treated group (7.2°).

Table III. Comparison of changes during phase 2 treatment (T2 to T3)

	Bionator + facebow (n = 24)		*Controls (n = 23)*			
Cephalometric measurements	*Mean*	*SD*	*Mean*	*SD*	*Difference*	*Significance*
Maxillary skeletal						
SNA angle (°)	−0.6	1.5	0.3	1.4	−0.9	*
Pt A to nasion perp (mm)	−0.9	1.2	0.1	1.3	−1.0	†
Co-Pt A (mm)	1.6	1.6	3.5	1.8	−1.9	‡
Mandibular skeletal						
SNB angle (°)	−0.2	1.2	1.2	1.0	−1.4	‡
Pog to nasion perp (mm)	−1.0	1.9	1.7	1.8	−2.7	‡
Co-Gn (mm)	3.5	1.9	7.4	3.2	−3.9	‡
Maxillary/mandibular						
ANB angle (°)	−0.4	1.0	−0.9	1.3	0.5	NS
Wits (mm)	−0.2	2.1	−0.4	1.7	0.2	NS
Maxillary/mandibular difference (mm)	1.9	1.4	3.9	2.8	−2.0	†
Vertical skeletal						
MPA (°)	0.5	1.8	−0.8	1.4	1.3	*
ANS to Me (mm) LAFH	2.8	2.2	4.0	2.4	−1.2	NS
Ar-Go (mm)	2.0	2.2	4.3	2.8	−1.3	†
N-Me (mm) AFH	4.6	3.0	7.3	3.2	−2.7	†
Co-Go (mm)	2.9	2.5	4.1	2.7	−1.2	NS
Gonial angle (°)	−1.0	2.6	−2.4	2.0	1.4	NS
FH to occlusal plane (°)	0.6	2.4	−2.1	2.5	2.7	†
FH to palatal plane (°)	0.0	2.1	−0.9	2.0	0.9	NS
Interdental						
Overbite (mm)	−0.9	1.2	−0.2	1.8	−0.7	NS
Overjet (mm)	−1.5	1.6	−0.9	1.1	−0.6	NS
Interincisal angle (°)	−4.6	9.4	3.7	6.9	−8.3	†
Molar relationship (mm)	−0.5	2.1	0.1	1.4	−0.6	NS
Maxillary dentoalveolar						
U1 to Pt A vert (mm)	−0.3	1.9	−0.2	1.1	−0.1	NS
U1 horizontal (mm)	−0.2	1.8	−0.3	1.3	0.1	NS
U1 vertical (mm)	0.9	1.2	1.4	1.0	−0.5	NS
U6 horizontal (mm)	2.2	2.0	1.8	1.8	0.4	NS
U6 vertical (mm)	1.3	1.3	1.2	1.6	0.1	NS
Mandibular dentoalveolar						
L1 to Pt A Pog (mm)	1.6	1.3	−0.2	1.2	1.8	‡
L1 horizontal (mm)	1.0	1.5	−0.3	1.4	1.3	†
L1 vertical (mm)	1.3	1.3	2.4	1.5	−1.1	*
L6 horizontal (mm)	1.3	1.4	1.1	1.3	0.2	NS
L6 vertical (mm)	1.7	1.4	2.6	1.7	−0.9	NS
L1 to MP (°)	5.2	5.1	−2.0	4.3	7.2	‡
Soft tissue						
UL to E plane (mm)	−1.4	1.8	−2.2	3.0	0.8	NS
LL to E plane (mm)	−0.2	1.7	−2.4	1.9	2.2	‡
Nasolabial angle (°)	−0.8	9.6	0.2	14.6	−1.0	NS

*$P < .05$; †$P < .01$; ‡$P < .001$; *NS,* not significant.

A significantly smaller decrease in the position of the lower lip to the esthetic plane was seen in the treated group vs the controls (2.2 mm).

Analysis of T1-T3 changes

The overall treatment produced a significantly larger decrease in Point A to nasion perpendicular and a significantly smaller increase in midfacial length compared with the controls (−1.1 mm and −1.9 mm, respectively) (Table IV, Figs 2 and 3). Pogonion to nasion perpendicular had significantly smaller increases in the treated group than in the untreated controls (−1.7 mm). No other significant differences were found between the 2 groups. During the treatment period (T1 to T3), no significant differences were noted for any maxillomandibular sagittal measurement between the 2 groups.

A significant increase in MPA was noted in the treated

Table IV. Comparison of changes during overall treatment (T1 to T3)

	Bionator + facebow (n = 24)		*Controls (n = 23)*			
Cephalometric measurements	*Mean*	*SD*	*Mean*	*SD*	*Difference*	*Significance*
Maxillary skeletal						
SNA angle (°)	−0.9	2.3	−0.1	2.0	−0.8	NS
Pt A to nasion perp (mm)	−1.4	1.6	−0.3	1.7	−1.1	*
Co-Pt A (mm)	4.9	2.0	6.8	3.1	−1.9	*
Mandibular skeletal						
SNB angle (°)	0.7	2.2	1.4	1.4	−0.7	NS
Pog to nasion perp (mm)	0.2	3.5	1.9	2.1	−1.7	*
Co-Gn (mm)	11.0	3.3	12.8	4.2	−1.8	NS
Maxillary/mandibular						
ANB angle (°)	−1.6	1.7	−1.5	1.4	0.1	NS
Wits (mm)	−1.0	2.5	−0.4	2.4	−0.6	NS
Maxillary/mandibular difference (mm)	6.1	2.8	6.0	3.1	0.1	NS
Vertical skeletal						
MPA (°)	0.8	2.2	−1.1	1.9	1.9	†
ANS to Me (mm) LAFH	6.2	2.2	6.2	2.8	0.0	NS
Ar-Go (mm)	5.1	2.9	6.3	2.7	−1.2	NS
N-Me (mm) AFH	12.6	3.8	13.2	4.8	−0.6	NS
Co-Go (mm)	6.0	3.7	6.5	2.4	−0.5	NS
Gonial angle (°)	−2.3	2.5	−4.0	3.0	1.7	*
FH to occlusal plane (°)	−1.1	2.9	−3.6	3.0	2.5	†
FH to palatal plane (°)	−2.0	2.3	−1.8	2.3	−0.2	NS
Interdental						
Overbite (mm)	0.1	3.2	1.0	2.7	−0.9	NS
Overjet (mm)	−2.6	2.1	−0.9	1.4	−1.5	†
Interincisal angle (°)	−0.4	11.1	5.2	8.4	−5.6	NS
Molar relationship (mm)	1.6	2.6	0.5	1.3	1.1	NS
Maxillary dentoalveolar						
U1 to Pt A vert (mm)	−0.1	1.9	0.5	1.5	−0.6	NS
U1 horizontal (mm)	−0.2	2.3	0.2	1.6	−0.4	NS
U1 vertical (mm)	2.7	1.8	3.2	1.7	−0.5	NS
U6 horizontal (mm)	2.6	2.3	2.5	1.6	0.1	NS
U6 vertical (mm)	1.9	1.9	1.8	1.8	0.1	NS
Mandibular dentoalveolar						
L1 to Pt A Pog (mm)	1.8	1.6	0.3	1.7	1.5	†
L1 horizontal (mm)	1.0	1.7	0.3	1.9	0.7	NS
L1 vertical (mm)	4.1	2.1	4.3	2.2	−0.2	NS
L6 horizontal (mm)	2.9	1.5	2.6	1.5	0.3	NS
L6 vertical (mm)	4.3	1.4	4.2	2.4	0.1	NS
L1 to MP (°)	1.9	6.9	−1.7	5.1	3.6	*
Soft tissue						
UL to E plane (mm)	−3.5	2.2	−3.9	2.7	0.4	NS
LL to E plane (mm)	−1.2	2.0	−2.8	1.9	1.6	*
Nasolabial angle (°)	2.6	9.9	4.0	13.9	−1.4	NS

*$P < .05$; †$P < .01$; *NS,* not significant.

group with respect to the decrease in the controls (1.9°). Significantly smaller decreases were found for both gonial angle and inclination of the occlusal plane to the Frankfort horizontal in the treated group compared with the controls during the observation period (1.7° and 2.7°, respectively).

The only dental measurement that showed a significant difference between the treated and the control groups was overjet, with a significantly greater decrease in the treated group than in the controls (−1.5 mm). No significant differences were found between the 2 groups for the T1 to T3 changes. A significantly greater increase in the sagittal position of the mandibular incisor (L1 to Pt A Pog vertical) was recorded in the treated group when compared with the untreated controls (1.5 mm). Significant flaring of the mandibular incisor (L1 to MP) was observed in the treated group (3.6°).

Table V. Comparison of final facial forms at T3

	Bionator + facebow (n = 24)		*Controls (n = 23)*			
Cephalometric measurements	*Mean*	*SD*	*Mean*	*SD*	*Difference*	*Significance*
Maxillary skeletal						
SNA angle (°)	80.2	4.0	80.4	3.7	−0.2	NS
Pt A to nasion perp (mm)	−0.9	2.7	−0.6	2.9	−0.3	NS
Co-Pt A (mm)	87.7	4.6	87.3	5.3	0.4	NS
Mandibular skeletal						
SNB angle (°)	75.8	4.1	76.7	3.4	−0.9	NS
Pog to nasion perp (mm)	−9.1	6.5	−6.4	4.7	−2.7	NS
Co-Gn (mm)	112.0	4.7	111.5	7.1	0.5	NS
Maxillary/mandibular						
ANB angle (°)	4.4	2.1	3.7	1.9	0.7	NS
Wits (mm)	0.7	2.4	0.5	3.5	0.2	NS
Maxillary/mandibular difference (mm)	24.3	4.4	24.2	3.7	0.1	NS
Vertical skeletal						
MPA (°)	30.8	4.7	28.3	3.8	2.5	*
ANS to Me (mm) LAFH	68.9	6.9	66.7	6.1	2.2	NS
Ar-Go (mm)	41.2	4.0	41.5	4.2	−0.3	NS
N-Me (mm) AFH	121.3	7.4	118.9	7.8	2.4	NS
Co-Go (mm)	49.2	4.8	46.3	3.7	2.9	*
Gonial angle (°)	129.3	5.9	127.7	5.3	1.6	NS
FH to occlusal plane (°)	10.4	3.0	7.6	2.9	2.8	†
FH to palatal plane (°)	−0.1	3.7	−0.3	3.1	0.2	NS
Interdental						
Overbite (mm)	1.3	0.9	1.9	2.1	−0.6	NS
Overjet (mm)	3.2	0.8	4.0	1.4	−0.8	*
Interincisal angle (°)	122.5	8.7	127.1	9.8	−4.6	NS
Molar relationship (mm)	1.2	2.3	0.9	1.1	0.3	NS
Maxillary dentoalveolar						
U1 to Pt A vert (mm)	3.9	2.3	4.4	2.1	−0.5	NS
Mandibular dentoalveolar						
L1 to Pt A Pog (mm)	3.4	1.7	1.9	2.4	1.5	*
L1 to MP (°)	95.9	7.6	94.2	6.6	1.7	NS
Soft tissue						
UL to E plane (mm)	−4.3	1.9	−5.2	2.9	−0.9	NS
LL to E plane (mm)	−0.3	3.0	−2.6	1.7	2.3	†
Nasolabial angle (°)	115.4	12.4	117.3	16.8	−1.9	NS

*P <.05; †P <.01; *NS,* not significant.

A significantly smaller decrease in the position of the lower lip to the esthetic plane was found in the treated group vs the controls during the observation period (1.6 mm).

Analysis of final forms

Significant between-group differences were noted for a few measurements (Table V). The treated group had a significantly larger MPA value (2.5°) than did the controls; posterior facial height (Co-Go) showed a greater value in the treated group (2.9 mm) vs the controls, and the angle between Frankfort horizontal and the occlusal plane opened 2.8°. Overjet was smaller in the final form for the treated group than in the control group (−0.8 mm). The mandibular incisor was in a more labial position in the treated group (L1 to Pt A-Pog) with respect to the controls (1.5 mm); this was associated with a less retrusive position of the lower lip to the E-plane (2.3 mm).

Analysis of skeletal maturation

The analysis of CVM at T1 showed that the 2 groups were nearly identical at the start. At T1, 88% of the treatment group were prepubertal (cervical stage [CS]1 and CS2) and 12% of the patients were pubertal (CS3); 83% of the control subjects were prepubertal and 17% of the subjects were pubertal.[28] Therefore, the 2 groups were well matched at T1 as to skeletal maturation.

The distribution of the maturational stages in the 2 groups was different at T2. The percentage of subjects who went through their pubertal growth spurt during T1 to T2 interval in the treated group (58%) was more than twice that of the subjects in the control group (26%). At T3, all subjects in both groups were at postpubertal stages of skeletal maturation. This means that only 42% of subjects in the treated group and 74% of the control group went through their pubertal peak during the T2 to T3 interval.

DISCUSSION

The lack of literature concerning nonsurgical treatment of the vertical dimension is in sharp contrast with the critical effect of vertical disharmonies on treatment outcomes in dentofacial orthopedics. One proposed treatment modality is a 2-phase protocol consisting of a bionator combined with a high-pull facebow, followed by fixed appliances in growing subjects.

To date, only 2 short-term investigations used untreated controls for the evaluation of the effectiveness of a protocol similar to that described above.[12,17] An activator as a fundamental part of the protocol implies that both the treated and the control groups described in the literature include patients with Class II dentoskeletal disharmonies. Stöckli and Teuscher[12] reported favorable dentoalveolar effects on the maxilla associated with an anterior position of the mandible. Data pertaining to the effects of this treatment protocol on vertical skeletal relationships were mentioned only briefly as an aside in the discussion of their investigation. Similarly, treatment effects in the vertical dimension were mentioned in passing in the more recent study by Sari et al.[17] They compared the effects of an activator-headgear combination with a removable Jasper jumper appliance-headgear combination and with an untreated control group. For the most part, they confirmed the results of Stöckli and Teuscher.[12] Their outcomes in terms of vertical skeletal changes were either insignificant or in some cases even unfavorable. To our knowledge, no studies have analyzed the efficacy of the bionator-facebow treatment protocol at a posttreatment observation, including a second phase of fixed appliances.

We examined the treatment effects of the bionator and high-pull facebow followed by fixed orthodontic appliances in growing subjects with mild-to-severe hyperdivergent facial patterns (greater than average value for MPA) with Class I or Class II malocclusions. Phase 1 treatment produced a significant increase in total mandibular length (Co-Gn) of about 2 mm more than in the controls, a modification that is favorable in Class II patients. During phase 2 treatment, however, the opposite was observed. Total mandibular length increased 4 mm less in the treated subjects than in the controls. After the study, the increments in total mandibular length in the bionator and high-pull facebow and the control groups were not distinguishable statistically.

There are 2 possible explanations for this observation. The first is that the treated patients simply were posturing their mandibles forward after treatment. The cephalometric analysis included a visual inspection of the relationship of the posterior border of the ramus to the anterior border of the second cervical vertebrae in serial films. No mandibular posturing was evident in any patient or subject.

The second interpretation can be derived by taking into account differences in skeletal maturation between the patients and the controls during the 2 phases of treatment with the CVM method.[28] The percentage of subjects who went through their pubertal growth spurts during the T1-T2 interval in the treated group (58%) was more than twice that of the subjects in the control group (26%). At T3, all subjects in both groups were at postpubertal stages of skeletal maturation. This means that only 42% of the subjects in the treated group and 74% of the control group went through the pubertal peaks during the T2 to T3 interval. The differences in timing of the pubertal skeletal growth spurt could account for the differential amount of supplementary mandibular growth between the 2 groups during the 2 phases.

As to the changes seen in the maxilla, there seems to be a significant amount of restriction in maxillary sagittal growth as a consequence of the overall treatment protocol (about 2 mm along Co-Pt A). Interestingly, this result was observed during the second phase of fixed appliances, not during the active orthopedic modification attempted during phase 1 treatment. This observation can be explained by the Class II mechanics such as elastics and the continued use of the high-pull facebow during fixed appliance therapy.

A unique feature of our investigation was the focus on the analysis of the changes in vertical skeletal relationships in treated and untreated hyperdivergent subjects. During the overall observation period, the treated group had more vertical growth—ie, an increase in MPA, rather than a decrease of the same angle in untreated vertical growers. The net difference for MPA was about 2°. A similar behavior occurred in both gonial angle and inclination of the occlusal plane to Frankfort horizontal. Both measurements had smaller decreases (2°-2.5°) when compared with the controls. The greatest increase in the vertical dimension took place during phase 2 treatment, when a significant increase in MPA was noted in the treated group with respect to the decrease seen in the controls (1.3°).

There were significant increases in lower and total anterior facial heights during phase 1 in the treated group; these findings were reversed during phase 2. These reversals can be explained again by the differences in timing of the pubertal growth spurt between the groups when describing the mandibular changes seen in this study. Moreover, it is well known that the use of a functional appliance to posture the mandible forward entails opening the bite as a consequence.[17-21]

It is interesting but not surprising that an appliance acting through the maxilla such as a bionator combined with high-pull headgear did not affect the inclination of the palatal plane relative to the Frankfort horizontal. Dermaut et al[11] studied the dental and skeletal effects of the headgear-activator and found that an orthopedic effect on the palatal plane could not be established. This lack of effect was recorded at both observation periods.

When analyzing the dentoalveolar and soft-tissue measurements, we found significant posttreatment differences represented primarily by the inclination of the mandibular incisor to the mandibular plane. During T1 to T2, significant lingual tipping of the mandibular incisor to the mandibular plane was observed. This finding was unusual; proclination, not retroclination, of the mandibular incisors (when capping of these teeth is not used) is common with bionator therapy.[21] However, during T2 to T3, a significant proclination of the mandibular incisor was reflected in the position of the lower lip to the esthetic plane; this expressed a significant tendency for protrusion when compared with the controls after the observation period.

Other statistically significant differences between treated and untreated subjects were noted from the 2-phase treatment. The absolute amount of between-group difference in change, however, did not reach clinical significance. Due to the power of the study, a net between-group difference of 2 mm or 2° must be considered the threshold for clinical significance. For instance, favorable changes such as an improvement of 1.5 mm in overjet, although statistically significant and reported in the tables, were not considered clinically significant and were not included in this discussion.

The between-group comparisons on both the initial and final forms were intended to test the hypothesis that 2-phase treatment with a bionator and high-pull headgear followed by fixed appliances would induce normalization of the hyperdivergent facial pattern in the treated subjects. This comparison was legitimatized by the similarity of the initial forms. The analysis of final forms provided no evidence of normalization of the initial problems in the vertical dimension. On the contrary, the final forms of the treated subjects demonstrated significantly more severe skeletal disharmonies in the vertical plane than the untreated subjects, at both the statistical and clinical levels. At the end of the observation period, the treated subjects showed a 2.5° greater opening of the MPA than did the controls.

Our results agree with those of Sari et al,[17] who reported worsening of the vertical skeletal relationships in subjects treated with a similar protocol. Based on this outcome and the limited information in the literature, the use of a bionator combined with high-pull headgear does not appear to be an effective treatment option in growing patients with increased vertical dimensions of the face. Even the modifications along the sagittal plane were minimal, especially when considering the burden of treatment. These modifications were represented mostly by restriction in maxillary growth that actually occurred during the fixed orthodontic appliance phase and were most likely the result of Class II mechanics such as elastics or continued use of the high-pull facebow.

CONCLUSIONS

This study was designed to evaluate the clinical impact of the first phase of bionator and high-pull headgear treatment followed by a second phase of fixed appliances in subjects with dental and skeletal vertical excesses to normalize their vertical dimensions during growth. The findings indicated that the bionator and high-pull headgear worsened the hyperdivergent facial pattern at a clinically significant level, as shown by the final facial forms. The treated group had a significantly larger MPA value than did the controls (2.5°) and a larger inclination of the Frankfort horizontal to the occlusal plane (2.8°).

The significant changes in jaw dimensions and relationships seen during phases 1 and 2 can be explained by between-group differences in timing of the pubertal growth spurt rather than by actual treatment effects. Our findings suggest that treatment with bionator and high-pull headgear is not recommended for growing patients with hyperdivergent facial patterns when the goal is to decrease the vertical dimensions of the face.

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