

# Treatment effects of bonded RME and vertical-pull chin cup followed by fixed appliance in patients with increased vertical dimension

Scott O. Schulz,<sup>a</sup> James A. McNamara, Jr,<sup>b</sup> Tiziano Baccetti,<sup>c</sup> and Lorenzo Franchi<sup>d</sup>

*Ann Arbor and Traverse City, Mich, and Florence, Italy*

**Introduction:** The aim of this study was to investigate the effectiveness of vertical-pull chin cup (VPCC) therapy during an initial rapid maxillary expansion (RME) phase, followed by a second phase of comprehensive orthodontic therapy in growing subjects with mild-to-severe hyperdivergent facial patterns. **Methods:** The records of 29 subjects treated with bonded RME combined with VPCC followed by a fixed-appliance phase with continued use of VPCC were compared with a group of 29 well-matched patients treated with bonded RME only. Lateral cephalograms were analyzed before the start of treatment (T1), before the second phase of treatment (T2), and after the second phase of treatment (T3). Mean age at T1 was approximately 9 years for both groups. Total treatment period (phase 1, interim phase, and phase 2) was 5.7 years for the VPCC group and 6.2 years for the bonded RME-only group. Statistical comparison between the 2 groups was performed by means of independent sample *t* tests on the T2-T1, T3-T2, and T3-T1 changes. Cervical vertebral maturation stages were assessed at T1, T2, and T3. **Results:** The VPCC induced significantly smaller increases in mandibular plane angle of about 2°, lower anterior facial height of about 2.5 mm, and total anterior facial height of about 3.5 mm, compared with the RME-only subjects. These outcomes reflect the therapeutic changes that occurred during phase 1 treatment; phase 2 treatment was not associated with any significant difference in treatment response. No statistically significant differences in vertical dentoalveolar changes were concurrent with the vertical skeletal changes in the subjects treated with the VPCC compared with the RME-only group. **Conclusions:** The clinical significance of VPCC wear over 2 phases of treatment (5.7 years) appears to be limited. The VPCC was most effective during the initial (RME) phase of treatment and of little benefit during the fixed appliance phase. (*Am J Orthod Dentofacial Orthop* 2005;128:326-36)

The treatment of patients with increased vertical dimensions (facial hyperdivergence or high-angle facial pattern) is commonly regarded as one of the most difficult challenges in orthodontics. The major characteristics of a hyperdivergent skeletal pattern are downward and backward rotation of the mandible, relative

mandibular retrognathia, and, commonly, anterior open bite.<sup>1-3</sup> Significant vertical skeletal imbalances are often accompanied by discrepancies in the anteroposterior and transverse dimensions.<sup>1</sup>

The multidimensional character of the hyperdivergent facial type complicates diagnosis and treatment planning. The underlying theme in treating high-angle patients is control of posterior dentoalveolar development<sup>4</sup> (tooth extrusion) to prevent increasing the vertical dimension during expansion and fixed appliance therapy. Such control can be particularly difficult because of the limited mechanical advantage inherent in this skeletal pattern.<sup>5</sup>

Various treatments have been proposed for patients with vertical dysplasia, with varying degrees of effectiveness, including extraction of posterior teeth,<sup>6,7</sup> high-pull headgear,<sup>8-10</sup> and the active vertical corrector.<sup>11,12</sup> Two appliances that have shown promise in posterior dentoalveolar control are posterior bite-blocks and the vertical-pull chin cup (VPCC). Advocates of posterior bite-blocks claim that acrylic coverage of the occlusal surfaces inhibits posterior eruption and might provide some intrusion of posterior teeth.<sup>13</sup> By design, the bonded, acrylic-splint,

<sup>a</sup>Former orthodontic resident, University of Michigan, Ann Arbor; private practice, Traverse City, Mich.

<sup>b</sup>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 scientist, Center for Human Growth and Development, University of Michigan, Ann Arbor; private practice, Ann Arbor, Mich.

<sup>c</sup>Assistant professor, Department of Orthodontics, University of Florence, Italy; Thomas M. Graber visiting scholar, Department of Orthodontics and Pediatric Dentistry, School of Dentistry, University of Michigan, Ann Arbor.

<sup>d</sup>Research associate, Department of Orthodontics, University of Florence, Italy; Thomas M. Graber visiting scholar, Department of Orthodontics and Pediatric Dentistry, School of Dentistry, University of Michigan, Ann Arbor.

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, School of Dentistry, University of Michigan, Ann Arbor, MI 48109-1078; e-mail, menamara@umich.edu.

Submitted, October 2003; revised and accepted, March 2004.

0889-5406/\$30.00

Copyright © 2005 by the American Association of Orthodontists.

doi:10.1016/j.ajodo.2004.03.039

**Table I.** Demographics of treatment times

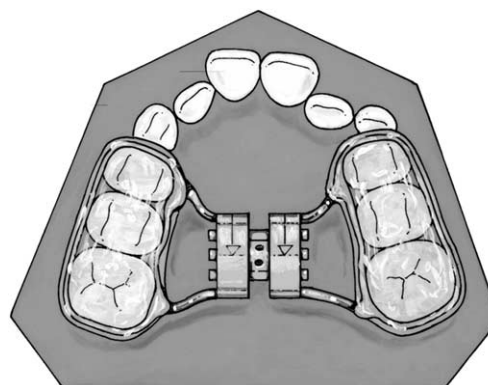
Treatment group	T1				T1-T2		T2-T3		T1-T3	
	Age (y)				(y)		(y)		(y)	
	Mean	SD	Min	Max	Mean	SD	Mean	SD	Mean	SD
RME-VPCC										
Boys (13)	8.9	0.9	7.2	10.8	3.2	1.1	2.7	0.8	5.8	1.2
Girls (16)	9.2	1.1	7.2	11.6	2.4	1.5	3.1	0.7	5.5	1.5
Total (29)	9.1	1.0	7.2	11.6	2.8	1.3	2.9	0.8	5.7	1.4
RME-only										
Boys (13)	8.9	1.0	7.2	10.2	4.1	1.0	2.4	1.1	6.6	1.0
Girls (16)	9.2	1.1	7.8	11.4	3.3	1.0	1.8	0.7	5.0	1.1
Total (29)	9.0	1.0	7.2	11.4	3.9	1.1	2.3	0.9	6.2	1.3

Min, minimum; Max, maximum.

rapid maxillary expander (RME) has a posterior bite-block effect as one of its modes of action. The nature of high-angle malocclusion often makes maxillary expansion necessary, and bonded acrylic expanders have been suggested for correction of the transverse dimension in these patients.<sup>4</sup> Studies have shown that this appliance minimizes tipping of the posterior maxillary teeth, thereby providing better control over the vertical dimension.<sup>14,15</sup>

VPCC therapy has the goal of preventing extrusion of molars and the resultant elongation of the lower face during orthodontic treatment.<sup>6,16-19</sup> The line of action of this chin cup closely approximates that of the masticatory muscles, so it should be of great value in treating patients of this facial type. High-angle, open-bite patients treated with VPCC alone show decreases in mandibular plane and gonial angles, along with relative intrusion of the mandibular molars.<sup>20</sup> A recent, short-term investigation by Basciftci and Karaman<sup>21</sup> compared the effects of bonded RME therapy alone with bonded RME combined with VPCC. The combination of the 2 appliances appeared to be more effective in controlling mandibular posterior rotation and maxillary molar extrusion than the expander alone, thus confirming previous observations by Pearson and Pearson<sup>22</sup> and Sankey et al.<sup>23</sup>

Although numerous studies have examined the effects of combined bonded RME and VPCC therapy during phase 1 treatment, none has directly examined the effects of the VPCC during 2-phase treatment. Our objective was to investigate the effectiveness of VPCC therapy during an initial RME phase, followed by a second phase of fixed orthodontic therapy in growing subjects with mild-to-severe hyperdivergent facial patterns. We compared the skeletal and dentoalveolar changes induced by 2 treatment regimens: bonded RME combined with VPCC followed by a fixed appliance phase and continued use of the VPCC, and bonded RME only, followed by a phase of fixed appliances.



**Fig 1.** Bonded acrylic-splint RME (from McNamara and Brudon<sup>4</sup>).

#### MATERIAL AND METHODS

The bonded RME and VPCC (RME-VPCC) sample was obtained from a group of 37 patients from 2 private orthodontic practices. Both clinicians used similar treatment protocols and were experienced in the clinical manipulation of the chin cup and the bonded expander. They were asked to submit cephalograms of all patients treated with the RME-VPCC protocol regardless of treatment results or compliance. To be included in the study, patients were required to meet the following criteria:

1. Two-phase treatment consisting of bonded RME-VPCC wear followed by preadjusted edgewise orthodontic treatment associated with VPCC wear.
2. Pretreatment Angle Class I or Class II malocclusion.
3. No permanent teeth extracted before or during treatment.
4. No functional appliance therapy.
5. Three consecutive, good-quality lateral cephalograms with adequate landmark visualization and minimal or no rotation of the head, taken before

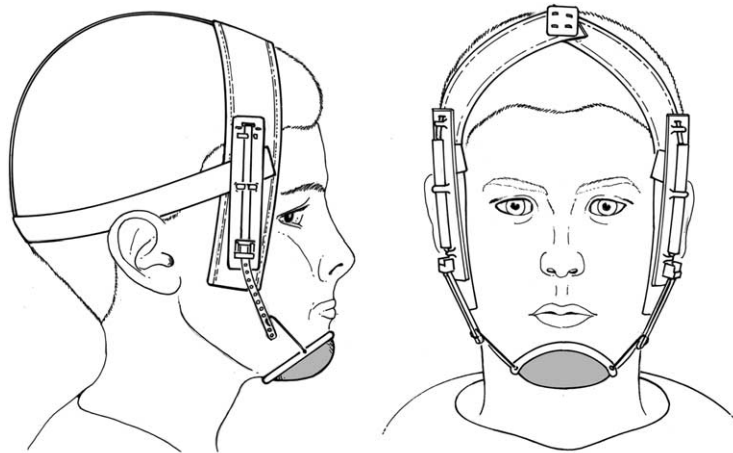


Fig 2. Frontal and lateral views of VPCC (from McNamara and Brudon<sup>4</sup>).

phase 1 treatment (T1), before phase 2 treatment (T2), and after phase 2 treatment (T3).

6. As derived from the cephalometric analysis at T1, mandibular plane angle (to Frankfort horizontal) of 25° or greater.<sup>24</sup>

Twenty-nine of the 37 subjects (16 girls and 13 boys) met the inclusion criteria. The average age of the RME-VPCC group at T1 and the mean treatment intervals for the sample and its sex subgroups are summarized in Table I.

The source of the bonded RME-only (RME-only) group records was a private group orthodontic practice. The practitioners were asked to provide records of all patients treated with the appliances regardless of treatment results or compliance. The same inclusion rules as in the RME-VPCC sample, with the exception of VPCC use, were applied to the RME-only sample.

The RME-only group was selected according to a case-control matching criterion. The main variables for the match between the 2 groups were age, sex, and values for mandibular plane angle and lower anterior facial height at T1. The final sample of 29 patients treated with bonded RME only during phase 1 treatment included 16 girls and 13 boys, the same sex distribution as the RME-VPCC group. The average age at T1 and the mean treatment intervals for the sample and its 2 subgroups are summarized in Table I.

#### Treatment protocols

In the RME-VPCC group, phase 1 treatment involved RME accompanied by VPCC therapy in the mixed dentition. Patients were treated with acrylic-splint RME composed of Hyrax-type screw (Leone,

Sesto Fiorentino, Italy) embedded into a wire-and-acrylic framework (Fig 1). The splint, made from 3-mm thick, heat-formed acrylic (Splint Biocryl, Great Lakes Orthodontics, Tonawanda, NY), was bonded to the deciduous molars and the permanent first molars. The expansion screw was turned once a day until the palatal cusps of the maxillary posterior teeth approximated the buccal cusps of the mandibular posterior teeth; then the appliance was left in place for 8 weeks. Immediately after RME removal, an occlusal-coverage maxillary retainer was fabricated to be worn full-time until phase 2 treatment.

Throughout the expansion phase and the retention period, the VPCC (Unitek Corporation, Monrovia, Calif) was worn (Fig 2). It consisted of a padded band that extended coronally, secured to the back of the head by a cloth strap. A spring mechanism was activated by pulling the tab inferiorly and attaching the tab to a hook on the hard chin cup. The vector of force (500 g [16 oz]) was directed approximately 90° to the occlusal plane. The VPCC was custom fitted for each patient, and the straps were stapled so as to fit the patient's head comfortably. The patients were instructed to wear it about 12 hours a day.

Phase 2 of treatment for the RME-VPCC group consisted of preadjusted fixed appliances. In addition to a standard archwire sequence, precision-adjusted, .036-in, stainless steel mandibular lingual and transpalatal arches were used. Patients were instructed to continue wearing it for 12 hours a day.

In the RME-only group, phase 1 treatment involved expansion with an acrylic RME appliance of the same type used in the RME-VPCC group. The expansion screw

**Table II.** Comparison of starting forms (T1)

Cephalometric measures	RME-VPCC (n = 29)		RME-only (n = 29)		Difference	Significance
	Mean	SD	Mean	SD		
Maxillary skeletal						
SNA (°)	79.1	3.6	79.6	3.3	0.5	NS
PtA to nasion perp (mm)	-1.0	3.2	-1.6	2.5	0.6	NS
Co-Pt A (mm)	84.9	4.1	86.9	4.6	5.0	NS
Mandibular skeletal						
SNB (°)	75.2	3.4	75.9	2.7	0.7	NS
Pog to nasion perp (mm)	-8.5	4.6	-9.4	4.8	0.9	NS
Co-Gn (mm)	108.5	4.9	108.1	5.4	0.4	NS
Maxillary/mandibular						
ANB (°)	3.9	2.1	3.6	2.0	0.3	NS
Wits (mm)	-0.2	3.1	-0.9	2.5	0.7	NS
Max/mand difference (mm)	23.6	3.1	21.2	3.0	2.4	*
Vertical skeletal						
MPA (°)	29.3	3.5	29.6	3.8	0.3	NS
ANS to Me (mm) LAFH	66.0	4.3	63.7	4.8	2.3	NS
Ar-Goi (mm)	39.4	3.8	38.5	3.6	0.9	NS
N-Me (mm) AFH	112.6	5.8	110.7	7.1	1.9	NS
Gonial angle (°)	131.7	5.4	132.9	5.7	1.2	NS
Co-Go (mm)	54.5	4.0	49.6	3.6	4.9	**
FH to occlusal plane (°)	10.8	3.3	11.3	2.7	0.5	NS
FH to palatal plane (°)	2.5	2.6	0.4	2.8	2.1	*
Interdental						
Overbite (mm)	2.4	2.3	2.5	2.3	0.1	NS
Overjet (mm)	4.7	2.0	4.8	1.7	0.1	NS
Interincisal angle (°)	128.1	7.5	125.5	7.4	2.6	NS
Molar relationship (mm)	0.8	1.7	0.7	1.0	0.1	NS
Maxillary dentoalveolar						
U1 to Pt A vert (mm)	4.4	1.8	3.8	2.0	0.6	NS
U1 to Frankfort (°)	112.7	6.0	113.8	5.5	1.1	NS
U6 to Frankfort (°)	76.6	3.6	74.6	4.1	2.0	NS
Mandibular dentoalveolar						
L1 to Pt A Pg (mm)	1.4	1.7	0.9	1.4	0.5	NS
L1 to MPA (°)	89.8	5.1	91.2	6.0	1.4	NS
Soft tissue						
UL to E plane (mm)	-2.3	2.0	-1.9	1.9	0.4	NS
LL to E plane (mm)	0.4	1.9	-0.1	2.3	0.5	NS
Nasolabial angle (°)	114.3	10.3	113.4	13.1	0.9	NS

\**P* < .01.

\*\**P* < .001.

NS, Not significant.

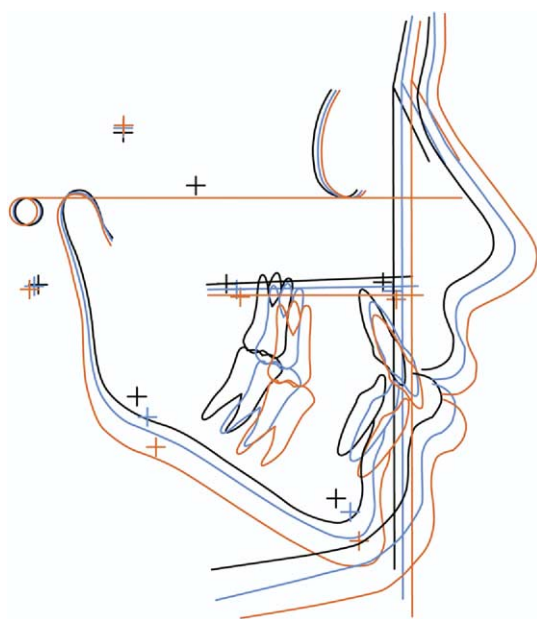
was turned once a day until the palatal cusps of the maxillary posterior teeth approximated the buccal cusps of the mandibular posterior teeth. The appliance then was left in place for approximately 5 months after expansion was complete. Immediately after RME debonding, a removable acrylic stabilization plate with arrow or ball clasp retention was fabricated for the maxilla. The patient was instructed to wear this full-time for at least 1 year and then at night until phase 2 treatment.

The fixed phase of treatment for the RME-only group also consisted of preadjusted fixed appliances. Stainless steel, .036-in transpalatal arches were used as

adjuncts to a standard archwire sequence. No extraoral forces were used.

### Cephalometric analysis

T1, T2, and T3 cephalograms were hand-traced by one investigator (S.O.S.) and verified for landmark location by a second (J.A.M.). Any disagreements were resolved by retracing the landmark or structure to the satisfaction of both observers. Cephalometric software (Dentofacial Planner, version 2.5; Dentofacial Software, Toronto, Ontario, Canada) was used for a customized digitization regimen that included 78 land-

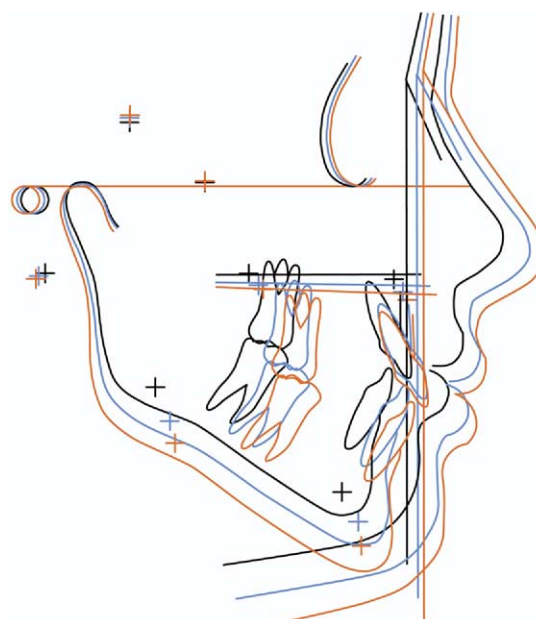


**Fig 3.** Average cephalometric forms for RME-VPCC group at T1 (black), T2 (blue), and T3 (red).

marks and 4 fiducial markers. This program allowed for analysis of cephalometric data and superimposition among serial cephalograms according to the specific needs of the 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 cephalograms was standardized at 8%. A cephalometric and regional superimposition analysis containing measures chosen from the analyses of McNamara,<sup>25</sup> McNamara et al,<sup>26,27</sup> Ricketts,<sup>28</sup> Steiner,<sup>29</sup> and the Wits appraisal<sup>30</sup> was performed on each cephalogram.

Cranial base superimpositions were performed by aligning the basion-nasion line and registering at the most posterosuperior aspect of the pterygomaxillary fissure.<sup>25,28</sup> In addition, the posterior cranial outline was used to verify the superimposition of cranial-base structures. From this superimposition, changes in position of the maxilla and the mandible were measured. To superimpose the maxilla along the palatal plane, the superior and inferior surfaces of the hard palate and the internal structures of the maxilla superior to the incisors were used as landmarks. From this superimposition, movement of the maxillary incisors and molars could be assessed. Mandibular superimposition included the mandibular canal and tooth germs posteriorly and the internal structures of the symphysis and contour of the chin anteriorly, allowing measurement of movement of the mandibular teeth.



**Fig 4.** Average cephalometric forms for RME-only group at T1 (black), T2 (blue), and T3 (red).

#### Cervical vertebral maturation analysis

Subjects in both groups were analyzed at T1, T2, and T3 with the recently improved version of the cervical vertebral maturation (CVM) method, a reliable means of assessing skeletal maturity.<sup>31</sup>

#### Statistical analysis

Means and standard deviations were calculated for age, duration of treatment, and all cephalometric measures at T1, T2, and T3 for the RME-VPCC and RME-only groups. Additionally, mean differences and standard deviations were calculated for the changes between T2 and T1, T3 and T2, and T3 and T1 for each group. The data were analyzed with software (version 10.0; SPSS, Inc, Chicago, Ill). Statistical significance was tested at the  $P < .05$ ,  $P < .01$ , and  $P < .001$  levels. The error of the data acquisition method has been described previously by McNamara et al.<sup>27</sup>

Starting forms and mean change differences at different time intervals (T2-T1, T3-T2, and T3-T1) were compared in the 2 groups with independent-sample  $t$  tests. Because of sample sizes in both groups ( $n = 29$ ), differences in vertical dimension change between treatment group effects were considered clinically significant if they were equal to or greater than 2 mm or  $2^\circ$  (statistical power of the study = 0.8).

**Table III.** Comparison of change during phase I treatment (T1 to T2)

Cephalometric measures	RME-VPCC (n = 29)		RME-only (n = 29)		Difference	Significance
	Mean	SD	Mean	SD		
<b>Maxillary skeletal</b>						
SNA (°)	0.5	1.7	0.0	1.4	0.5	NS
PtA to nasion perp (mm)	0.2	1.5	-0.4	1.2	0.6	NS
Co-Pt A (mm)	3.5	2.2	4.2	2.2	0.7	NS
<b>Mandibular skeletal</b>						
SNB (°)	0.8	1.4	1.0	1.4	0.2	NS
Pog to nasion perp (mm)	1.2	2.2	1.7	2.5	0.5	NS
Co-Gn (mm)	5.1	3.0	8.9	3.8	3.8	**
<b>Maxillary/mandibular</b>						
ANB (°)	-0.3	1.6	-1.0	1.3	0.7	NS
WITS (mm)	0.4	2.4	-1.0	1.9	1.4	NS
Max/mand difference (mm)	1.6	2.6	4.7	3.0	3.1	***
<b>Vertical skeletal</b>						
MPA (°)	-1.3	1.5	-0.3	1.7	1.0	NS
ANS to Me (mm) LAFH	1.0	2.6	3.8	2.3	2.8	**
Ar-Goi (mm)	2.6	2.8	4.1	3.3	1.5	NS
N-Me (mm) AFH	4.7	3.5	8.9	4.0	4.2	*
Co-Go (mm)	2.4	2.3	3.4	2.8	1.0	NS
Gonial angle (°)	-2.2	2.7	-1.8	2.8	0.4	NS
FH to occlusal plane (°)	-1.4	2.8	-0.8	2.3	0.6	NS
FH to palatal plane (°)	-1.2	1.6	-1.4	1.3	0.2	NS
<b>Interdental</b>						
Overbite (mm)	1.6	2.1	0.9	1.6	0.7	NS
Overjet (mm)	-0.4	1.8	-0.5	1.6	0.1	NS
Interincisal angle (°)	0.1	5.7	-0.7	5.5	0.8	NS
Molar relationship (mm)	1.0	1.9	0.9	1.5	0.1	NS
<b>Maxillary dentoalveolar</b>						
U1 to Pt A vert (mm)	0.5	1.3	1.3	1.8	0.8	NS
U1 horizontal (mm)	0.2	1.5	1.5	2.0	1.3	NS
U1 vertical (mm)	1.0	1.9	2.0	1.4	1.0	NS
U6 horizontal (mm)	0.5	1.6	2.1	1.8	1.6	*
U6 vertical (mm)	-0.1	1.9	1.3	1.4	1.4	*
<b>Mandibular dentoalveolar</b>						
L1 to Pt A Pg (mm)	0.4	1.5	0.9	1.5	0.5	NS
L1 horizontal (mm)	0.2	1.3	-0.1	1.5	0.3	NS
L1 vertical (mm)	2.1	1.2	3.0	1.2	0.9	NS
L6 horizontal (mm)	1.5	1.3	1.1	1.3	0.4	NS
L6 vertical (mm)	1.1	1.8	2.6	1.1	1.5	*
L1 to MPA (°)	1.2	4.1	0.0	3.4	1.2	NS
<b>Soft tissue</b>						
UL to E plane (mm)	-1.7	1.5	-2.0	1.7	0.3	NS
LL to E plane (mm)	-0.8	1.6	-1.0	2.2	0.2	NS
Nasolabial angle (°)	1.5	7.7	-0.3	7.7	1.8	NS

\**P* < .05.

\*\**P* < .01.

\*\*\**P* < .001.

NS, Not significant.

## RESULTS

Descriptive statistics including means and standard deviations for both groups at the start of treatment are presented in Table II. The mean value of the mandibular plane relative to Frankfort horizontal for both groups was 29° (range 25° to 38°). The RME-VPCC group initially

had a larger mandibular ramus height (Co-Go) and a larger maxillary-mandibular discrepancy. In addition, the anterior portion of the palatal plane was inclined more superiorly in the RME-VPCC group than in the RME-only group. No other significant differences were found between the 2 groups at T1.

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

Cephalometric measures	RME -VPCC n = 29		RME-only n = 29		Difference	Significance
	Mean	SD	Mean	SD		
Maxillary skeletal						
SNA (°)	-1.5	1.9	-0.7	1.6	0.8	NS
PtA to nasion perp (mm)	-1.5	2.0	-0.8	1.8	0.7	NS
Co-Pt A (mm)	2.5	2.3	2.3	2.4	0.2	NS
Mandibular skeletal						
SNB (°)	-0.3	1.2	-0.3	1.4	0.0	NS
Pog to nasion perp (mm)	0.1	2.6	-0.3	2.7	0.4	NS
Co-Gn (mm)	7.5	3.3	5.7	3.7	1.8	NS
Maxillary/mandibular						
ANB (°)	-1.2	1.5	-0.5	1.6	0.7	NS
WITS (mm)	-0.6	2.8	-0.1	1.6	0.5	NS
Max/mand difference (mm)	5.1	2.4	3.5	2.5	1.6	NS
Vertical skeletal						
MPA (°)	-0.2	1.8	0.6	1.9	0.8	NS
ANS to Me (mm) LAFH	4.5	2.8	4.3	2.4	0.2	NS
Ar-Goi (mm)	4.0	2.7	3.0	3.0	1.0	NS
N-Me (mm) AFH	8.2	4.2	7.3	4.0	0.9	NS
Co-Go (mm)	4.1	2.9	3.1	4.1	1.0	NS
Gonial angle (°)	-2.3	2.7	-1.0	2.7	1.0	NS
FH to occlusal plane (°)	-1.3	3.2	-0.3	2.1	1.0	NS
FH to palatal plane (°)	-1.0	1.7	-0.9	1.6	0.1	NS
Interdental						
Overbite (mm)	-1.7	1.8	-1.8	1.6	0.1	NS
Overjet (mm)	-1.3	1.8	-1.3	1.5	0.0	NS
Interincisal angle (°)	-6.5	9.9	-3.0	8.2	3.5	NS
Molar relationship (mm)	0.2	2.0	0.7	1.4	0.5	NS
Maxillary dentoalveolar						
U1 to Pt A vert (mm)	0.5	2.0	-0.3	2.4	0.8	NS
U1 horizontal (mm)	0.4	2.1	-0.8	2.0	1.2	NS
U1 vertical (mm)	0.6	1.7	0.2	1.3	0.4	NS
U6 horizontal (mm)	2.1	2.2	1.2	1.6	0.9	NS
U6 vertical (mm)	1.2	1.6	0.9	1.5	0.3	NS
Mandibular dentoalveolar						
L1 to Pt A Pg (mm)	1.3	1.7	0.9	1.7	0.4	NS
L1 horizontal (mm)	0.5	1.5	0.3	1.3	0.2	NS
L1 vertical (mm)	2.4	1.5	2.6	1.8	0.2	NS
L6 horizontal (mm)	1.1	1.3	1.4	1.2	0.3	NS
L6 vertical (mm)	3.6	2.1	3.3	1.6	0.3	NS
L1 to MPA (°)	3.5	6.0	1.6	4.4	1.4	NS
Soft tissue						
UL to E plane (mm)	-2.0	1.6	-1.6	2.0	0.4	NS
LL to E plane (mm)	-1.3	1.5	-0.6	1.9	0.7	NS
Nasolabial angle (°)	-0.6	9.2	3.8	7.1	4.4	NS

NS, Not significant.

There were no significant differences between the 2 groups for any maxillary measures in the sagittal plane from T1 to T2 (phase 1 treatment) (Table III). Total mandibular length (Co-Gn) showed a significantly larger increase in the RME-only group when compared with the RME-VPCC group (3.8 mm). No other significant changes in mandibular measures could be detected. During phase 1 treatment, the RME-only group had a significantly greater increase in maxillary-man-

dibular differential (3.1 mm). The changes in the Wits appraisal and the ANB angle were not significantly different in the 2 groups.

Significantly greater differences were found for the increase in lower anterior facial height (ANS to Me) in the RME-only group (2.8 mm). Similarly, the increase in the total anterior facial height (N-Me) was significantly greater in the RME-only group than in the RME-VPCC group (4.2 mm).

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

Cephalometric measures	RME-VPCC n = 29		RME-only n = 29		Difference	Significance
	Mean	SD	Mean	SD		
Maxillary skeletal						
SNA (°)	-1.0	2.5	-0.7	1.8	0.3	NS
PtA to nasion perp (mm)	-1.3	2.4	-1.2	1.9	0.1	NS
Co-Pt A (mm)	5.9	3.1	6.5	3.1	0.6	NS
Mandibular skeletal						
SNB (°)	0.6	1.9	0.7	2.2	0.1	NS
Pog to nasion perp (mm)	1.4	3.1	1.4	4.1	0.0	NS
Co-Gn (mm)	12.6	4.7	14.7	4.7	2.1	NS
Maxillary/mandibular						
ANB (°)	-1.6	2.0	-1.4	1.7	0.2	NS
WITS (mm)	-0.2	3.4	-1.1	2.0	0.9	NS
Max/mand difference (mm)	6.7	3.4	8.2	2.8	1.5	NS
Vertical skeletal						
MPA (°)	-1.6	1.9	0.2	2.8	1.8	**
ANS to Me (mm) LAFH	5.5	4.1	8.1	2.8	2.6	**
Ar-Goi (mm)	6.7	2.9	7.1	3.6	0.4	NS
N-Me (mm) AFH	12.9	5.8	16.2	4.5	3.3	*
Co-Go (mm)	6.5	3.1	6.6	3.7	0.1	NS
Gonial angle (°)	-4.6	3.1	-2.8	3.6	1.8	NS
FH to occlusal plane (°)	-2.7	3.5	-1.1	3.1	1.6	NS
FH to palatal plane (°)	-2.3	1.9	-2.3	1.8	0.0	NS
Interdental						
Overbite (mm)	-0.1	2.3	-0.9	2.2	0.8	NS
Overjet (mm)	-1.7	2.1	-1.8	1.6	0.1	NS
Interincisal angle (°)	-6.4	10.1	-3.7	9.3	2.7	NS
Molar relationship (mm)	1.2	1.9	1.6	1.1	0.4	NS
Maxillary dentoalveolar						
U1 to Pt A vert (mm)	1.0	2.1	1.0	3.0	0.0	NS
U1 horizontal (mm)	0.6	2.6	0.7	2.4	0.1	NS
U1 vertical (mm)	1.6	1.8	2.2	1.6	0.6	NS
U6 horizontal (mm)	2.6	2.3	3.3	2.1	0.7	NS
U6 vertical (mm)	1.1	2.0	2.3	1.4	1.2	NS
Mandibular dentoalveolar						
L1 to Pt A Pg (mm)	1.7	2.1	1.8	1.5	0.1	NS
L1 horizontal (mm)	0.7	1.9	0.1	1.7	0.6	NS
L1 vertical (mm)	4.5	2.1	5.6	2.4	1.1	NS
L6 horizontal (mm)	2.7	1.7	2.6	1.8	0.1	NS
L6 vertical (mm)	4.7	2.7	5.9	1.9	1.2	NS
L1 to MPA (°)	4.8	6.0	1.6	4.0	3.2	NS
Soft tissue						
UL to E plane (mm)	-3.7	1.8	-3.6	1.7	0.1	NS
LL to E plane (mm)	-2.0	1.6	-1.5	2.2	0.5	NS
Nasolabial angle (°)	0.9	8.7	3.5	8.3	2.6	NS

\**P* < .05;

\*\**P* < .01.

NS, Not significant.

Significantly greater treatment changes were noted for the position of the maxillary first molar in both the horizontal and vertical planes in the RME-only group (approximately 1.5 mm for both horizontal and vertical). A significantly larger increase in the vertical position of the mandibular first molar was recorded in the RME-only group compared with the RME-VPCC

group (1.5 mm). No significant between-group differences were found for the T1-to-T2 changes in interdental relationships.

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

No significant differences were found between the



groups for the changes from T2 to T3 (phase 2 treatment) for any cephalometric measures (Table IV).

When the overall treatment changes were examined from T1 to T3 (approximately a 6-year treatment period), significant between-group differences were confined to vertical skeletal measures (Table V). The RME-VPCC group showed significantly smaller increases in mandibular plane angle, lower anterior facial height, and total anterior facial height. The mandibular plane angle increased  $1.8^\circ$  less in the RME-VPCC group than in the RME-only group. Similar trends were recorded for the other 2 measures, which demonstrated 2.6 mm less increase in lower anterior facial height and 3.3 mm less increase in total anterior facial height in the RME-VPCC group.

A graphic representation of treatment change for the RME-VPCC group is given in the composite tracing of treatment forms at T1, T2, and T3 (Fig 3). Figure 4 is a composite tracing of the RME-only group at each of these time periods.

At T1, the 2 groups had identical outcomes, with equal distributions of the CVM stages (CVMS) (CVMS I = 17; CVMS II = 2; CVMS III = 1). The distribution of the maturational stages in the 2 groups was different at T2. The percentage of subjects who went through their pubertal growth spurts during the T1-T2 interval in the RME-only group (69%) was almost twice that of subjects in the RME-VPCC group (38%). At the end of fixed appliance treatment, 2 patients in the RME-VPCC group still had not experienced their growth peaks as measured by the CVM method. Only 6 (21%) subjects in the RME-VPCC group had reached CVMS V at the end of orthodontic treatment, compared with 14 (48%) of the RME-only group.

## DISCUSSION

This study examined the effectiveness of VPCC therapy during an initial RME phase and secondary fixed orthodontic therapy in growing subjects with mild-to-severe hyperdivergent facial patterns. No previous data were found in the literature evaluating treatment of patients with increased vertical dimensions that included a second phase of comprehensive fixed appliance therapy.

The 2 groups examined in this study were well matched as to starting forms. Significant between-group differences were noted for only a few measures. The RME-VPCC group initially had a greater mandibular ramus height and a larger maxillary-mandibular discrepancy. The anterior portion of the palatal plane was inclined more superiorly in the RME-VPCC group than in the RME-only group. Because the 2 groups were clinically managed nearly identically over the 2

phases of therapy, with the exception of the extraoral orthopedic force used in the RME-VPCC group, it can be inferred that the differences in treatment outcomes were due mostly to the use of the VPCC.

## Treatment effects

After phase 1 treatment, there was an effective reduction in the vertical measures for anterior facial height as a result of VPCC wear, which resulted in smaller increases in both lower and total anterior facial heights (2.8 mm and 4.0 mm, respectively) in comparison with the RME-only group. These differences were significant both statistically and clinically.

The reduced increase in vertical dimension during phase 1 treatment with the VPCC was associated with significantly less extrusion of both the maxillary and mandibular first molars. These teeth demonstrated 1.5 mm less extrusion in the RME-VPCC group than in the RME-only group. This combined increase in posterior dentoalveolar height (3 mm) for the RME-only group is reflected in the difference of the net change in lower anterior facial height for the 2 groups at the start of fixed appliance therapy. Both the dentoalveolar and skeletal changes in the vertical dimension occurred without a significant change in the inclination of the mandibular plane angle, which showed a nonsignificant  $1^\circ$  difference between the 2 groups after phase 1 treatment. These results are similar to those reported by Pearson and Pearson<sup>22</sup> and Basciftci and Karaman.<sup>21</sup>

A highly significant difference in the increase in total mandibular length (Co-Gn) from T1 to T2 was recorded between the 2 groups, with the RME-VPCC group showing almost 4.0 mm less growth than the RME-only group at the end of phase 1. Two explanations are proposed for the observed difference in mandibular growth. The first hypothesis takes into account a possible restrictive effect of chin cup wear on mandibular growth. Because of the vertical direction of the orthopedic force, the effect on anteroposterior growth might be limited; however, some restrictive effect on mandibular growth is not out of the question in view of the compressive force on the mandibular condyle. The investigations by Petrovic et al<sup>32</sup> and Petrovic<sup>33</sup> showed that increases in mandibular length are less when compressive forces are placed against the mandibular condyle, at least over the short term.

The second explanation is the possibility of a significant difference in the maturational status of the patients in the 2 groups during phase 1 treatment. Analysis of CVM on the lateral cephalograms at T1 and T2 shows that 70% of the subjects in the RME-only group experienced the pubertal peak in mandibular growth during phase 1. In contrast, only 40% of the

subjects in the RME-VPCC group had their growth spurts during that phase. Duration of treatment time also might have played a role in the difference in mandibular growth changes. The RME-only group phase 1 treatment interval (including the so-called interim period between phase 1 and phase 2) was longer (47 months) than the interval for the RME-VPCC group (34 months).

The VPCC appears to have little effect on the cephalometric parameters of vertical change during fixed appliance therapy. Changes from T2 to T3 for patients treated without extraoral force (RME-only group) were not statistically different from those observed in the RME-VPCC group. In fact, the between-group differences during this phase were almost negligible and certainly were not clinically significant.

Mandibular anteroposterior growth showed a reverse pattern from phase 1 during the T2-T3 interval, with a 2.0 mm greater increase in the RME-VPCC group than in the RME-only group. This difference might be because more subjects in the RME-VPCC group (50%) than in the RME-only group (30%) underwent the pubertal peak in mandibular growth during this period.

The effectiveness of the VPCC as a means to control vertical hyperdivergence was tested on the overall changes from T1 to T3. Because the treatment regimens and times for the 2 groups were nearly identical, it can be concluded that the VPCC is responsible for differences between the groups. Through the combination of phase 1 and phase 2 treatment outcomes, VPCC wear resulted in significantly smaller increases in lower anterior facial height (-2.6 mm), total anterior facial height (-3.4 mm), and inclination of the mandibular plane to Frankfort (-1.8°). The changes in these parameters were statistically significant when compared with the RME-only group. Additionally, a greater, though not significantly different, closure of the gonial angle (-1.8°) was observed in the RME-VPCC group.

No statistically significant differences in vertical dentoalveolar changes were concurrent with the vertical skeletal changes. The RME-VPCC group experienced 2 mm less extrusion of both the maxillary and mandibular molars when compared with the RME-only group, but the difference was not statistically significant.

The analysis of the overall changes for total mandibular length from T1 to T3 showed a 2 mm greater increase in length in the RME-only group. This finding can be explained on the basis of the higher percentage of treated subjects having completed active growth (CVMS V) at T3 in the RME-only group (50%) with respect to the RME-VPCC group (20%).

Although the VPCC was relatively more effective in controlling the vertical dimension, the bonded RME did not increase the severity of the hyperdivergence to a clinically significant degree. The primary treatment objective for RME therapy is not correction of the vertical skeletal imbalance, as is the case with the VPCC. Therefore, the bonded RME treatment modality can be used with a reasonable level of confidence for the treatment of various dentoskeletal problems (eg, posterior crossbite, maxillary transverse deficiency, tooth size-arch size discrepancy, mild Class II malocclusion) in the hyperdivergent patient.

The VPCC can partially control posterior dental eruption and vertical dimension increases. However, the clinical significance of increases of 2° less in mandibular plane angle and 2.5 mm less in lower anterior face height over 2 phases of treatment (5.7 years) seems small when one considers the burden of chincup wear over the course of treatment compared with RME-only treatment. The VPCC was most effective during the initial (RME) phase of treatment but of minimal benefit during the fixed-appliance phase.

## CONCLUSIONS

1. Over a 2-phase treatment period (5.7 years), wearing a VPCC in combination with a bonded acrylic splint extender during phase 1 and later with fixed appliances can significantly limit the increases in mandibular plane angle (to about 2°), lower anterior facial height (to about 2.5 mm), and total anterior facial height (to about 3.5 mm) when compared with subjects treated with expanders (RME) and fixed appliances only.
2. No statistically significant differences in vertical dentoalveolar changes were concurrent with the vertical skeletal changes in subjects treated with the VPCC compared with the RME-only group.
3. When the overall treatment effects are evaluated, most of the positive effects attributed to the VPCC were achieved during the RME phase (phase 1), whereas only a minor benefit of the extraoral appliance was seen during phase 2, the comprehensive, fixed-appliance phase.

We thank Drs Lloyd Pearson and Ronald Snyder, who provided treatment records for the RME and VPCC samples, and Drs Patrick Nolan and Kristine West, who collaborated with Dr McNamara in collecting records for the RME-only sample.

## REFERENCES

1. Proffit WR. The development of vertical dentofacial problems: concepts from recent human studies. In: McNamara JA Jr, editor. The enigma of the vertical dimension. Monograph 36. Cranio-

- facial Growth Series. Ann Arbor: Center for Human Growth and Development; University of Michigan; 2000.
2. Proffit WR, Bailey LJ, Phillips C, Turvey TA. Long-term stability of surgical open-bite correction by LeFort I osteotomy. *Angle Orthod* 2000;70:112-7.
  3. Buschang P, Sankey W, English JD. Early treatment of hyperdivergent open-bite malocclusions. *Semin Orthod* 2002;8:130-40.
  4. McNamara JA Jr, Brudon WL. Orthodontics and dentofacial orthopedics. Ann Arbor, Mich: Needham Press; 2001.
  5. Proffit WR, Fields HW, Nixon WL. Occlusal forces in normal and long-face children. *J Dent Res* 1983;62:571-4.
  6. Pearson LE. Vertical control through use of mandibular posterior intrusive forces. *Angle Orthod* 1973;43:194-200.
  7. Staggers JA. Vertical changes following first premolar extractions. *Am J Orthod Dentofacial Orthop* 1994;105:19-24.
  8. Kuhn RJ. Control of anterior vertical dimension and proper selection of extraoral anchorage. *Angle Orthod* 1968;38:340-9.
  9. Firouz M, Zernik J, Nanda R. Dental and orthopedic effects of high-pull headgear in treatment of Class II Division 1 malocclusion. *Am J Orthod Dentofacial Orthop* 1992;102:197-205.
  10. Baumrind S, Korn EL, Isaacson RJ, West EE, Molthen R. Quantitative analysis of the orthodontic and orthopedic effects of maxillary traction. *Am J Orthod* 1983;84:384-98.
  11. Dellinger EL. Active vertical corrector treatment—long-term follow-up of anterior open bite treated by the intrusion of posterior teeth. *Am J Orthod Dentofacial Orthop* 1996;110:145-54.
  12. Cavanaugh CE, Christiansen RL. The effect of active vertical corrector treatment in growing anterior open-bite patients. In: McNamara JA Jr, editor. The enigma of the vertical dimension. Monograph 36. Craniofacial Growth Series. Ann Arbor: Center for Human Growth and Development; University of Michigan; 2000.
  13. Kuster R, Ingervall B. The effect of treatment of skeletal open bite with two types of bite-blocks. *Eur J Orthod* 1992;14:489-99.
  14. Sarver DM, Johnston MW. Skeletal changes in vertical and anterior displacement of the maxilla with bonded rapid palatal expansion appliances. *Am J Orthod Dentofacial Orthop* 1989;95:462-6.
  15. Asanza S, Cisneros GJ, Nieberg LG. Comparison of hyrax and bonded expansion appliances. *Angle Orthod* 1997;67:15-22.
  16. Speidel TM, Isaacson RJ, Worms FW. Tongue-thrust therapy and anterior dental open-bite. A review of new facial growth data. *Am J Orthod* 1972;62:287-95.
  17. Pearson LE. Vertical control in treatment of patients having backward-rotational growth tendencies. *Angle Orthod* 1978;48:132-40.
  18. Pearson LE. Vertical control in fully-banded orthodontic treatment. *Angle Orthod* 1986;56:205-24.
  19. Pearson LE. The management of vertical problems in growing patients. In: McNamara JA Jr, editor. The enigma of the vertical dimension. Monograph 36. Craniofacial Growth Series. Ann Arbor: Center for Human Growth and Development; University of Michigan; 2000.
  20. Iscan HN, Dincer M, Gultan A, Meral O, Taner-Sarisoy L. Effects of vertical chin cap therapy on the mandibular morphology in open-bite patients. *Am J Orthod Dentofacial Orthop* 2002;122:506-11.
  21. Basciftci FA, Karaman AI. Effects of a modified acrylic bonded rapid maxillary expansion appliance and vertical chin cap on dentofacial structures. *Angle Orthod* 2002;72:61-71.
  22. Pearson LE, Pearson BL. Rapid maxillary expansion with incisor intrusion: a study of vertical control. *Am J Orthod Dentofacial Orthop* 1999;115:576-82.
  23. Sankey WL, Buschang PH, English J, Owen AH. Early treatment of vertical skeletal dysplasia: the hyperdivergent phenotype. *Am J Orthod Dentofacial Orthop* 2000;118:317-27.
  24. McNamara JA Jr, Brudon WL. Orthodontic and orthopedic treatment in the mixed dentition. Ann Arbor, Mich: Needham Press; 1993.
  25. McNamara JA Jr. A method of cephalometric evaluation. *Am J Orthod* 1984;86:449-69.
  26. McNamara JA Jr, Bookstein FL, Shaughnessy TG. Skeletal and dental changes following functional regulator therapy on Class II patients. *Am J Orthod* 1985;88:91-110.
  27. McNamara JA Jr, Howe RP, Dischinger TG. A comparison of the Herbst and Fränkel appliances in the treatment of Class II malocclusion. *Am J Orthod Dentofacial Orthop* 1990;98:134-44.
  28. Ricketts RM. Perspectives in the clinical application of cephalometrics. The first fifty years. *Angle Orthod* 1981;51:115-50.
  29. Steiner CC. Cephalometrics for you and me. *Am J Orthod* 1953;39:729-55.
  30. Jacobson A. The "Wits" appraisal of jaw disharmony. *Am J Orthod* 1975;67:125-38.
  31. Baccetti T, Franchi L, McNamara JA Jr. An improved version of the cervical vertebral maturation (CVM) method for the assessment of mandibular growth. *Angle Orthod* 2002;72:316-23.
  32. Petrovic A, Stutzmann JJ, Oudet C. Control process in the postnatal growth of the condylar cartilage. In: McNamara JA Jr, editor. Determinants of mandibular form and growth. Monograph 4. Craniofacial Growth Series. Ann Arbor: Center for Human Growth and Development; University of Michigan; 1975.
  33. Petrovic A. Experimental and cybernetic approaches to the mechanism of action of functional appliances on mandibular growth. In: Ribbens KA, editor. Malocclusion and the periodontium. Monograph 15. Craniofacial Growth Series. Ann Arbor: Center for Human Growth and Development; University of Michigan; 1984.