ORIGINAL ARTICLE

Treatment timing for an orthopedic approach to patients with increased vertical dimension

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Introduction: The aim of this study was to investigate the role of treatment timing on the effectiveness of vertical-pull chincup (V-PCC) therapy in conjunction with a bonded rapid maxillary expander (RME) in growing subjects with mild-to-severe hyperdivergent facial patterns. **Methods:** The records of 39 subjects treated with a bonded RME combined with a V-PCC were compared with 29 untreated subjects with similar vertical skeletal disharmonies. Lateral cephalograms were analyzed before (T1) and after treatment or observation (T2). Both the treated and the untreated samples were divided into prepubertal and pubertal groups on the basis of cervical vertebral maturation (prepubertal treated group, 21 subjects; pubertal treated group, 18 subjects; prepubertal control group, 15 subjects; pubertal control group, 14 subjects). Mean change differences from T2 to T1 were compared in the 2 prepubertal and the 2 pubertal groups with independent-sample *t* tests. **Results:** No statistically significant differences between the 2 prepubertal groups were found for any cephalometric skeletal measures from T1 to T2. When compared with the untreated pubertal sample, the group treated with the RME and V-PCC at puberty showed a statistically significant reduction in the inclination of the mandibular plane to the Frankfort horizontal (−2.2 mm), a statistically significant reduction in the inclination of the condylar axis to the mandibular plane (−2.2°), and statistically significant supplementary growth of the mandibular ramus (1.7 mm). **Conclusions:** Treatment of increased vertical dimension with the RME and V-PCC protocol appears to produce better results during the pubertal growth spurt than before puberty, although the absolute amount of correction in the vertical skeletal parameters is limited. (Am J Orthod Dentofacial Orthop 2008;133:58-64)

The clinical management of malocclusions characterized by skeletal open bite is often a challenging task for the orthodontist. To limit the number of subjects requiring orthognathic surgery for the correction of their facial vertical disharmony, early treatment of the dentoskeletal open bite in the mixed or early permanent dentition has been advocated by several authors with various treatment modalities, including extraction of posterior teeth,[1,2] high-pull headgear,[3-5] and the active vertical corrector.[6,7] A rather extensively studied treatment approach to skeletal open bite is vertical-pull chincup (V-PCC) therapy in conjunction with a bonded rapid maxillary expander (RME). The goal of this treatment protocol is to prevent posterior extrusion of the molars and the resultant elongation of the lower face during orthodontic treatment.[8-15] The combination of the 2 appliances appears to be more effective in controlling mandibular posterior rotation and maxillary molar extrusion than the expander alone.[13-15] A recent study demonstrated that, during 2-phase treatment period, wear of a V-PCC can induce significantly smaller increases in mandibular plane angle, lower anterior facial height, and total anterior facial height when compared with subjects treated with the expander and fixed appliances only.[15]

When analyzing the relevant literature, it is apparent that the definition of early treatment of vertical dysplasia refers to the timing of orthodontic or orthopedic treatment with regard to orthognathic surgery. No information is provided about possible differences in treatment effectiveness when therapy for excessive vertical dimension is attempted at a prepubertal stage vs a pubertal stage of skeletal maturity. Previous research clearly demonstrated the importance of the inclusion of the pubertal peak in treatment regimens aimed to enhance mandibular growth.[16-21] Because obtaining increased vertical growth of the mandibular ramus with

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Table I. Descriptive statistics of ages and observation periods

	Age		
Group	T1	T2	T2-T1
P-PTG (n = 21)	8 y 8 mo ± 9 mo	11 y 5 mo ± 9 mo	2 y 7 mo ± 11 mo
P-PCG (n = 18)	8 y 5mo ± 1 y	11 y 2 mo ± 11 mo	2 y 8 mo ± 11 mo
PTG (n = 15)	9 y 4 mo ±1 y 1 mo	12 y 4 mo ± 10 mo	3 y ± 10 mo
PCG (n = 14)	9 y 10 mo ± 1 y 3 mo	13 y 1 m ± 11 mo	3 y 2 mo ± 11 mo

closure of the gonial angle and anterior growth rotation of the mandible are fundamental parts of the correction mechanism of skeletal hyperdivergency with orthopedic appliances (such as RME and V-PCC),[11-15] it appears legitimate to hypothesize an influence of timing on treatment outcomes for skeletal open-bite therapy at the circumpubertal period.

The purpose of this investigation, therefore, was to compare the effects of bonded RME combined with V-PCC in skeletal open-bite patients treated before and during the adolescent growth spurt with control samples of untreated subjects with similar vertical disharmony and biological indicators of skeletal maturity.

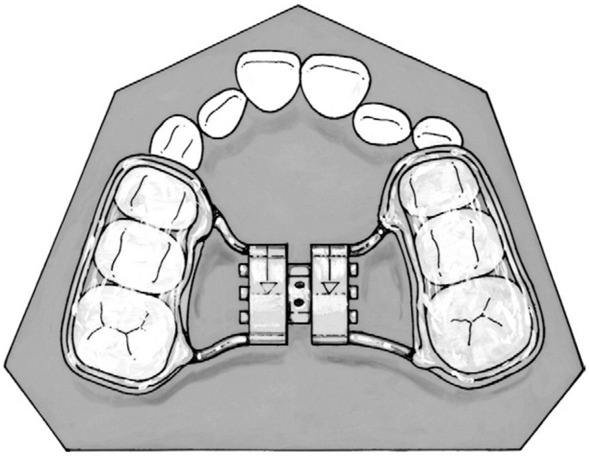

Fig 1. Bonded acrylic splint RME.

MATERIAL AND METHODS

The bonded RME and V-PCC sample consisted of 39 patients (21 girls, 16 boys) from 2 private orthodontic practices. The practitioners were asked to submit cephalograms of patients treated consecutively with the bonded RME and V-PCC protocol regardless of treatment results or compliance. To be included in the study, patients were required to meet the following criteria: (1) no permanent teeth extracted before or during treatment, (2) no functional appliance therapy, (3) 2 consecutive quality lateral cephalograms with adequate landmark visualization and with minimal or no rotation of the head, taken before (T1) and after treatment (T2), and (4) as derived from the cephalometric analysis at T1, a mandibular plane angle to Frankfort horizontal (MPA) of 25° or greater.[19]

A control group of 29 subjects (15 girls, 14 boys) was selected from the archives of the University of Michigan Elementary and Secondary School Growth Study. The control sample matched the treated sample as to hyperdivergent facial pattern (MPA ≥ 25°), mean age at T1 and T2, and mean observation period.

The subjects in both groups were analyzed at T1 and T2 with a reliable method for the assessment of skeletal maturity: the recently improved version of the cervical vertebral maturation method.[21] Identification of the maturational stages assisted in the definitions of the groups according to treatment timing.

Both the treated and the untreated samples were divided into prepubertal and pubertal groups (prepubertal treated group, P-PTG; pubertal treated group, PTG; prepubertal control group, P-PCG; and pubertal control group, PCG). The prepubertal groups were either treated or observed before the peak in skeletal growth (cervical stage [CS] 1 at T1, and CS 2 or CS 3 at T2), whereas the pubertal growth spurt was included during the treatment or observation period for the pubertal groups (CS 3 at T1, and CS 4 or CS 5 at T2). Approximately equal numbers of prepubertal and pubertal treated subjects came from the 2 practices.

The average ages at T1 and T2 and the average observation intervals for all groups are reported in Table I.

Treatment involved RME accompanied by V-PCC therapy. Patients were treated with an acrylic splint RME appliance composed of a Hyrax-type screw (Leone, Sesto Fiorentino, Italy) embedded in a framework of wire and acrylic (Fig 1). The splint, made from 3-mm thick heat-formed acrylic splint, was bonded to the deciduous molars and the permanent first molars with light-cured composite. The expansion screw was turned once a day until the palatal cusps of the maxillary posterior teeth approximated the buccal cusps of the

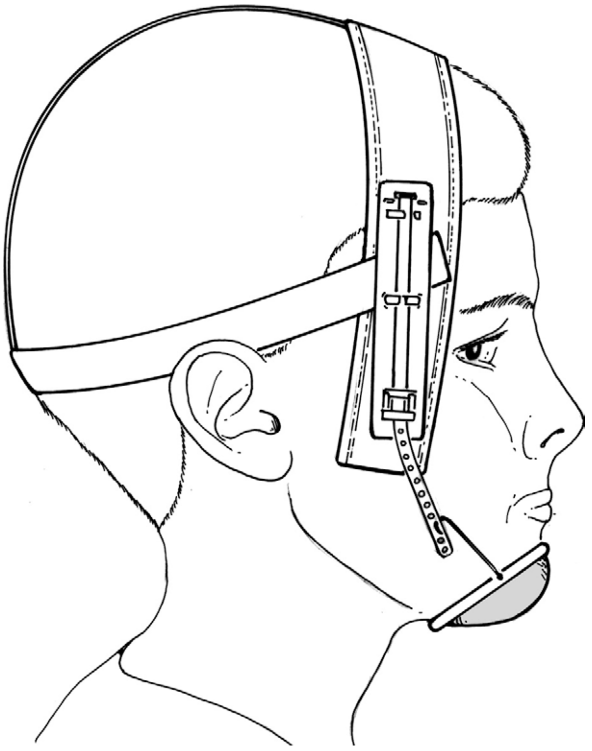

Fig 2. Lateral view of the V-PCC.

mandibular posterior teeth. The appliance then was left in place for 8 weeks after expansion was complete. Immediately after RME removal, an occlusal-coverage maxillary retainer was fabricated, and the patient was instructed to wear it full time.

Throughout the expansion and retention phases, the V-PCC (3M Unitek, Monrovia, Calif) was worn (Fig 2). The chincup consisted of a padded band that extended coronally and was secured to the posterior part 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 a hard chincup. The vector of force was directed approximately 90° to the occlusal plane. The chincup was custom fitted for each patient, and the straps were stapled as necessary to fit the patient's head comfortably. Patients were instructed to wear the chincup about 12 hours a day, with a force of 500 g (16 oz) generated.

Cephalometric software (version 2.5; Dentofacial Planner, Toronto, Ontario, Canada) was used for a customized digitization regimen of cephalometric tracings that included 78 landmarks and 4 fiducial markers. This program allowed for analysis of the cephalometric data and superimposition of serial cephalograms according to our needs.

Lateral cephalograms for each patient at T1 and T2 were digitized, and 51 variables were generated for each film. The magnification factor of the cephalograms was standardized at 8%. The cephalometric analysis was performed by an examiner (S.O.S.) who was blind as to the prepubertal and pubertal group assignment.

A cephalometric and regional superimposition analysis with measures chosen from the analyses of McNamara,[22] McNamara et al,[23,24] Ricketts,[25] Steiner,[26] and Ødegaard,[27] and the Wits appraisal[28] was performed on each cephalogram. The cranial base superimpositions were made by aligning the basion-nasion line and registering at the most posterosuperior aspect of the pterygomaxillary fissure. In addition, the posterior cranial outline was used to verify the superimposition of cranial-base structures. From this superimposition, changes in positions 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, the movement of the maxillary incisors and molars could be assessed. The mandibular superimposition was performed by using the mandibular canal and tooth germs posteriorly, and the internal structures of the symphysis and anterior contour of the chin anteriorly. This superimposition allowed the measurement of movement of the mandibular teeth.

Statistical analysis

Means and standard deviations were calculated for all cephalometric measures at T1 and T2 for the RME and V-PCC and the control groups. Additionally, mean differences and standard deviations were calculated for the changes between T2 and T1 for each group. The data were analyzed with SPSS software (version 12.0; SPSS, Chicago, Ill). Statistical significance was tested at the $P < .05$ level. The error of the data acquisition method was described previously by McNamara et al.[24]

An exploratory Shapiro-Wilks test was performed on all variables to test the normality of the sample. The results were not significant and indicated normality of distribution for the examined parameters and recommended parametric statistics. Multivariate linear models with Hotelling T^2 statistics were applied to the craniofacial starting forms (T1) (data available from the authors on request) in the 2 prepubertal groups and the 2 pubertal groups. The 2 models were not significantly different, indicating that the treated and control groups were well matched as to craniofacial measures at the first observation. Mean change differences from T2 to T1 were compared in the 2 prepubertal and the 2 pubertal groups with independent-sample *t* tests ($P < .05$). Due to the sample sizes of both groups, a statistical power of the study of 0.83 can be assessed in case of between-group differences with regard to vertical dimension changes equal to or greater than 1.5 mm or 1.5°.

RESULTS

There were no significant differences between the 2 groups for any cephalometric measures from T1 to T2. The only exception was a statistically significant intrusion of the maxillary molars (−1.1 mm). All differences between the P-PTG and the P-PCG with regard to the skeletal vertical parameters were within 0.5 mm or 0.5° (Table II).

When compared with the untreated pubertal sample, the PTG showed significant differences in vertical skeletal measurements. A significant reduction in the inclination of the mandibular plane to the Frankfort horizontal (MPA) was found (−2.2. mm). This change was associated with a significant reduction in the inclination of the condylar axis to the mandibular plane (−2.2°) and significant supplementary growth of the mandibular ramus (1.7 mm) (Table III).

DISCUSSION

The aim of this study was to evaluate the role of treatment timing for an orthopedic approach to increased vertical dimension of the face with a bonded RME and a V-PCC. We used untreated controls with the same type of skeletal disharmony as the treated subjects. No previous data are available in the literature with regard to the evaluation of treatment protocols in patients with increased vertical dimension that include an analysis of the influence of differential treatment timing according to skeletal maturity. The cervical vertebral maturation method was used to classify treated and untreated patients into 2 categories: prepubertal (with both T1 and T2 observations before the accelerated portion of the peak in mandibular growth) and pubertal (with the T1 observation before the pubertal peak and the T2 observation after the peak in mandibular growth).[21]

A previous study of the effectiveness of RME and V-PCC on dentoskeletal open-bite malocclusion did not consider the timing of therapy.[15] That study reported that, during the 2-phase treatment period, wearing a V-PCC 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 when compared with subjects treated with the expander and fixed appliances only. No statistically significant differences in vertical dentoalveolar changes were concurrent with the vertical skeletal changes in subjects treated with the V-PCC compared with the RME-only group. When the overall treatment effects were evaluated, it was evident that most of the positive effects attributed to the V-PCC were achieved during the RME phase (phase I), whereas only minor benefits of the extraoral appliance was seen during phase II, the comprehensive fixed appliance phase of treatment. For this reason, we focused on the role of treatment timing on treatment outcomes for the RME and V-PCC protocol during phase I only.

The analysis of our results indicates that, when orthopedic treatment of skeletal open bite is attempted at a prepubertal stage in skeletal maturation (CS 1 to CS 2 or CS 3), no significant favorable changes in the dentofacial complex can be induced with the proposed protocol compared with the growth changes of untreated controls with the same type of disharmony. Statistically significant intrusion of the maxillary molars is a result of the use of the bonded RME and the V-PCC, but the amount of the effect was limited (1.1 mm).

On the contrary, when the pubertal growth spurt was included in the treatment or observation period (CS 3 to CS 4, or to CS 5), significant changes in the vertical skeletal measurements could be seen in the treated group when compared with the corresponding untreated group. Significant differences between the pubertal treated and control groups demonstrated a favorable effect of the orthopedic protocol on the vertical relationships: reductions in the inclination of the mandibular plane to the Frankfort horizontal, the inclination of the condylar axis to the mandibular plane, the inclination of the mandibular plane to the palatal plane, and both total and lower anterior facial heights. These modifications were associated with significant supplementary growth of the mandibular ramus. The amounts of the differences between the treated group and the controls, although significant, were moderate (range, 1.5 to 2.2 mm or degrees).

These findings agree with extensive literature emphasizing the importance of including the pubertal peak in treatment regimens aimed to enhance mandibular growth.[16-21] Since increased vertical growth of the mandibular ramus and closure of the gonial angle are fundamental parts of the correction mechanism of skeletal hyperdivergency with orthopedic appliances (such as RME and V-PCC),[11-15] therapy during the mandibular growth spurt can induce more significant clinical outcomes when compared with therapy at a prepubertal stage in development.

Table II. Comparisons of T2-T1 changes between prepubertal treated and control groups (prepubertal treatment did not include pubertal peak in mandibular growth, started at CS 1, and ended at CS 2 or CS 3)

	P-PTG (n = 21)		*P-PCG (n = 18)*			
Cephalometric measures	*Mean*	*SD*	*Mean*	*SD*	*P-PTG vs P-PCG*	*Significance*
Maxillary skeletal						
SNA angle (°)	0.4	1.4	−0.2	1.3	0.6	NS
Pt A to nasion perp (mm)	0.2	1.3	0.1	1.7	0.1	NS
Co-Pt A (mm)	2.7	1.8	3.7	2.0	−1.0	NS
Mandibular skeletal						
SNB angle (°)	0.9	1.1	0.5	1.3	0.4	NS
Pog to nasion perp (mm)	1.5	2.4	1.4	3.1	0.1	NS
Co-Gn (mm)	4.3	2.1	5.7	2.5	−1.4	NS
Maxillary/mandibular						
ANB angle (°)	−0.5	0.8	−0.7	1.1	0.2	NS
Wits (mm)	−0.3	1.1	0.2	1.8	−0.5	NS
Max/mand difference (mm)	1.6	1.0	2.0	1.3	−0.4	NS
Vertical skeletal						
FH to palatal plane (°)	0.8	1.4	0.4	2.1	0.4	NS
MPA (°)	−1.2	2.0	−1.3	1.9	0.1	NS
Pal. pl. to mand. pl. (°)	2.1	2.6	−1.7	1.9	−0.4	NS
N-ANS (mm)	2.9	1.1	3.2	1.6	−0.3	NS
ANS to Me (mm)	1.0	2.0	2.3	2.1	−1.3	NS
N-Me (mm)	4.2	2.1	5.6	2.9	−1.4	NS
Co-Go (mm)	2.5	2.0	2.9	2.1	−0.4	NS
Gonial angle (°)	−1.7	2.5	−1.8	3.0	0.1	NS
Condax to mand. plane (°)	−1.3	2.6	−1.2	2.3	−0.1	NS
Interdental						
Overjet (mm)	−0.3	1.6	0.0	1.1	−0.3	NS
Overbite (mm)	1.9	1.9	1.5	1.9	0.4	NS
Interincisal angle (°)	1.4	7.0	−0.7	4.1	2.1	NS
Molar relationship (mm)	0.7	1.6	0.1	1.0	0.6	NS
Maxillary dentoalveolar						
U1 to Pt A vert (mm)	0.6	1.5	1.0	1.4	−0.4	NS
U1 to FH (°)	−0.1	5.8	1.0	3.3	−1.1	NS
U1 horizontal (mm)	1.0	1.7	1.1	1.7	−0.1	NS
U1 vertical (mm)	1.2	1.8	1.8	1.7	−0.6	NS
U6 horizontal (mm)	0.9	1.6	0.4	1.7	0.5	NS
U6 vertical (mm)	0.9	1.1	2.0	1.1	−1.1	*
Mandibular dentoalveolar						
L1 to Pt A Pg (mm)	0.1	0.9	0.2	1.1	−0.1	NS
L1 to MPA (°)	−0.1	4.1	1.0	2.8	−1.1	NS
L1 horizontal (mm)	−0.1	0.9	0.2	1.2	−0.3	NS
L1 vertical (mm)	1.7	0.9	2.1	1.5	−0.4	NS
L6 horizontal (mm)	0.4	1.5	0.0	1.2	0.4	NS
L6 vertical (mm)	1.5	1.1	1.2	1.1	0.3	NS
Soft tissue						
UL to E-plane (mm)	0.6	1.3	1.1	1.9	−0.5	NS
LL to E-plane (mm)	−1.1	5.0	0.8	6.3	−1.9	NS
Nasolabial angle (°)	−1.2	11.2	0.5	11.4	−1.7	NS

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

Interestingly, a previous investigation on the effectiveness of RME and V-PCC treatment did not detect a statistically significant change in the inclination of the mandibular plane angle when compared with the outcomes of RME-only treatment after phase I treatment.[15] Similar results were reported by Basciftci and Karaman[12] and Pearson and Pearson.[13] When analyzed on the basis of treatment timing, a statistically significant mean change in the inclination of the mandibular angle (−2.2°) became apparent in the group treated during the pubertal growth spurt compared with the PCG in our study. These findings imply that the use of the appliance at an appropriate biological time during skeletal develop-

Table III. Comparison of T2-T1 changes between pubertal treated and control groups (pubertal treatment included the pubertal peak in mandibular growth, started at CS 3, and ended at CS 4 or CS 5)

	PTG (n = 15)		PCG (n = 14)			
Cephalometric measures	*Mean*	*SD*	*Mean*	*SD*	*PTG vs PCG*	*Significance*
Maxillary skeletal						
SNA angle (°)	0.7	1.6	0.4	1.1	0.3	NS
Pt A to nasion perp (mm)	1.3	1.3	0.7	1.4	0.6	NS
Co-Pt A (mm)	4.9	2.0	5.2	2.3	−0.3	NS
Mandibular skeletal						
SNB angle (°)	1.0	1.0	0.3	1.5	0.7	NS
Pog to nasion perp (mm)	3.3	3.3	1.6	3.0	1.7	NS
Co-Gn (mm)	8.0	2.8	7.7	2.4	0.3	NS
Maxillary/mandibular						
ANB angle (°)	−0.3	1.5	0.2	1.1	−0.5	NS
Wits (mm)	0.4	2.5	1.1	1.9	−0.7	NS
Max/mand difference (mm)	3.1	2.5	2.5	2.2	0.6	NS
Vertical skeletal						
FH to palatal plane (°)	−0.3	1.6	0.2	1.7	−0.5	NS
MPA (°)	−2.9	2.2	−0.7	2.2	−2.2	*
Pal. pl. to mand. pl. (°)	−2.6	1.9	−1.1	2.3	−1.5	NS
N-ANS (mm)	2.5	1.1	3.6	2.0	−1.1	NS
ANS to Me (mm)	2.4	2.3	4.0	2.4	−1.6	NS
N-Me (mm)	5.1	2.5	6.9	3.1	−1.8	NS
Co-Go (mm)	5.8	2.2	4.1	1.5	1.7	*
Gonial angle (°)	−2.5	2.0	−0.7	3.8	−1.8	NS
Condax to mand. plane (°)	−1.9	1.9	0.3	2.8	−2.2	*
Interdental						
Overjet (mm)	−0.2	1.4	0.2	1.4	−0.4	NS
Overbite (mm)	1.8	1.7	0.2	2.2	1.6	NS
Interincisal angle (°)	1.1	5.4	4.6	6.2	−3.5	NS
Molar relationship (mm)	−0.1	2.7	0.3	3.3	−0.4	NS
Maxillary dentoalveolar						
U1 to Pt A vert (mm)	1.0	1.3	0.4	1.2	0.6	NS
U1 to FH (°)	1.4	5.2	−1.0	3.2	2.4	NS
U1 horizontal (mm)	1.2	1.6	0.5	1.9	0.7	NS
U1 vertical (mm)	1.7	1.5	1.7	2.0	0.0	NS
U6 horizontal (mm)	1.0	1.3	0.1	3.2	0.9	NS
U6 vertical (mm)	2.0	1.3	1.9	1.3	0.1	NS
Mandibular dentoalveolar						
L1 to Pt A Pg (mm)	0.3	1.3	−0.3	1.2	0.6	NS
L1 to MPA (°)	0.5	3.7	−0.7	3.7	1.2	NS
L1 horizontal (mm)	0.5	1.3	−0.5	1.2	1.0	NS
L1 vertical (mm)	2.9	1.5	1.9	1.2	1.0	NS
L6 horizontal (mm)	0.4	2.7	−0.1	5.6	0.5	NS
L6 vertical (mm)	2.6	2.0	1.9	1.3	0.7	NS
Soft tissue						
UL to E-plane (mm)	0.8	1.6	1.6	2.1	−0.8	NS
LL to E-plane (mm)	1.7	5.4	1.7	5.3	0.0	NS
Nasolabial angle (°)	−4.2	8.2	0.3	9.5	−4.5	NS

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

ment maximizes the effectiveness of the treatment regimen on the craniofacial structures in skeletal open-bite patients. However, the absolute amount of modification that the RME and V-PCC protocol induces in an average patient with increased vertical dimension appears limited, even when treatment is performed at the pubertal stage of skeletal development. Therefore, caution is warranted in the use of this treatment modality for the correction of the disharmony in growing patients.

CONCLUSIONS

Treatment of patients with increased vertical dimension with a bonded RME in conjunction with a

V-PCC during the adolescent spurt in mandibular growth appeared to induce more favorable changes than prepubertal treatment. These changes included reduction in the inclination of the mandibular plane to the Frankfort horizontal, reduction in the inclination of the condyle to the mandibular plane, and increased growth of the mandibular ramus.

The sizes of these favorable treatment effects were small (the greatest linear difference between the treated and untreated subjects was 2.2 mm; the greatest angular difference was 1.5°). Therefore, caution is recommended in the use of this treatment protocol at both prepubertal and pubertal stages. No statistically significant changes were found when treatment was performed at the prepubertal stage of skeletal maturity.

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