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Research

Vertical control in Class II hyperdivergent growing patients using miniscrew implants: a pilot study

Peter H. Buschang [a,*], Helder B. Jacob [a], Michael P. Chaffee [b]

[a] Department of Orthodontics, Baylor College of Dentistry, Texas A&M Health Science Center, Dallas, Texas
[b] Private Practice, Coeur D'Alene, Idaho

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A B S T R A C T

Background: The aim of this study was to determine if miniscrew implants (MSIs) can be used to control vertical development and improve the facial profile of Class II growing hyperdivergent patients.
Methods: The sample includes 18 hyperdivergent patients (12.3 ± 1.8 years of age) who were consecutively treated using MSIs to intrude the maxillary and mandibular molars. They were matched to untreated controls based on age, sex, and the mandibular plane angle. Lateral cephalograms were taken immediately before and after treatment (2.5 ± 0.9 years treatment duration). Growth and treatment changes of 11 linear and angular measurements, as well as the horizontal and vertical movements of 6 landmarks, were described using cranial base, maxillary, and mandibular superimpositions.
Results: The upper molars of the treated patients were held in place vertically (0.3 mm), whereas they erupted significantly in the control group (1.5 mm). In contrast, the lower molars erupted significantly more (1.8 mm) in the treated patients than control group. The sella-nasion-pogonion and sella-nasion-B angles increased significantly more (0.5° and 0.7°, respectively) in the treated patients than in the control group. Group differences in true rotation (0.4°) were not statistically significant. Individual differences in true rotation showed moderately high negative correlations with the horizontal movements of pogonion (−0.722) and moderately negative correlations with sella-nasion-pogonion (−0.690) and sella-nasion-B (−0.699).
Conclusions: Treatment of growing hyperdivergent patients with MSIs successfully controls the vertical and improves facial profile. Greater improvements could have been attained if supraeruption of the lower molar had been better controlled.

1. Introduction

Hyperdivergent patients present with numerous three-dimensional dental and skeletal problems pertaining to both the maxilla and mandible that could compromise their aesthetics and function. Except for the Class IIIs, they exhibit retrognathic mandibles, long anterior facial heights, large mandibular plane angles, large gonial angles, and greater than average lower-to-upper anterior facial height ratios [1,2]. Dentally, they often present with open bites and overerupted incisors and molars [2]. When the transverse dimensions of hyperdivergent patients have been evaluated, the maxilla is often reported to be narrow with an increased incidence of posterior cross bites [2]. Aesthetically, their convex profiles make hyperdivergent patients less attractive [3,4]. Hyperdivergent patients also have been associated with smaller, less active muscles and weaker bite forces [5–7].

Treatment of retrognatic hyperdivergent patients has proven to be extremely challenging. Orthodontists have traditionally addressed the vertical dimension of growing hyperdivergent patients with high-pull headgear, both with and without extractions, but this approach appears to have little or no effect on the anteroposterior position of the mandible [8–11]. Vertical chin cups, which have been used to reduce the mandibular plane angle, limit increases in anterior facial height, increase posterior heights, redirect condylar growth, and decrease gonial angulation [12], but require excellent long-term patient cooperation. Currently, surgery is the most effective way to address the dysmorphology associated to hyperdivergent patients [13], but surgery is expensive and it is not recommended for growing patients.

Successful treatment of hyperdivergent patients depends on the orthodontist's ability to control vertical tooth movements and

* Corresponding author: Orthodontic Department, Baylor College of Dentistry, Texas A&M Health Science Center, 3302 Gaston Ave, 75246, Dallas, Texas.
E-mail address: phbuschang@bcd.tamhsc.edu (P.H. Buschang).

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rotate the mandible. True mandibular rotation, as defined by Solow and Houston [14], has been found to be the most important determinant of the anteroposterior position of the chin in untreated and treated patients [15,16]. True forward mandibular rotation has been associated with greater chin projection, reductions in the gonial angle, redirection of condylar growth, and control of vertical eruption [15,16]. Patients with short and long faces have smaller and larger dentoalveolar heights, respectively. If molar eruption keeps pace with mandibular rotation, then controlled eruption might be an effective way to produce orthopedic changes [15,16]. This indicates that control of eruption could be used to produce rotation.

Skeletal anchorage provides an effective way to control vertical tooth movements and rotate the mandible. Miniplates and miniscrews implants (MSIs) have been used to successfully treat hyperdivergent adults by intruding the molars; this approach decreases the mandibular plane angle, increases in the sella nasion point B (SNB) angle, and relatively decreases lower face height [17–21]. However, the available literature provides few guidelines for growing adolescents, who comprise most of the orthodontic cases being treated. Based on nine consecutively treated hyperdivergent adolescent patients, Buschang et al. [21] recently reported major orthopedic changes produced by intruding/holding the maxillary and mandibular molars, including substantial advancement of the chin, autorotation of the mandible, decreases of the gonial angle, and improvements of facial convexity. However, their data are preliminary and based on a small sample.

The purpose of this nonrandomized cohort study was to evaluate whether MSIs can be effectively used in growing hyperdivergent patients to control the vertical dimension and improve chin position. Based on comparisons of patients treated with MSIs and untreated controls, the aims were to evaluate differences in:

- Dental and skeletal changes that occurred over time
- Changes in the amount and direction of “true” mandibular rotation
- Relationships between true rotation and changes in chin position

2. Methods and materials

This retrospective, longitudinal, study pertains to 18 consecutively treated hyperdivergent patients (5 males, 13 females), who started treatment at 12.3 ± 1.8 years of age. The patients were selected based on their age and the use of MSIs sometime during treatment to control the eruption of their posterior teeth; 13 patients (72%) had MSIs placed in the maxilla only; 5 patients (28%) had MSIs placed in both jaws. The sample comprised patients with Class II malocclusions; 72% of the patients had extractions. Of those who had extraction, 77% had maxillary extractions and 23% had maxillary and mandibular extractions. All of the patients were treated orthodontically with fixed appliances.

The untreated control group included 18 children who were followed longitudinally at the Human Growth Research Center, University of Montreal, Canada. They came from three school districts in Montreal representing various socioeconomic strata of the larger population [22]. They were matched to the treated group based on their angle classification, pretreatment age, post-treatment age, sex, and pretreatment mandible plane angle (sella to nasion [S-N]/ gonion to menton [Go-Me]).

Standardized pretreatment (T1) and immediately posttreatment (T2) lateral cephalograms, taken with the head positioned using the Frankfort horizontal, were traced on acetate paper. The tracings were digitized and analyzed with Viewbox 3.1-Cephalometric Software, version 3.1.1.14 (Dhal Software, Athens, Hellas, Greece) by one investigator (H.J.). The linear measurements were adjusted to eliminate magnification. The analyses describe growth and treatment changes of 23 traditional dental and skeletal measurements, derived from 10 landmarks (Fig. 1).

The horizontal and vertical movements of six landmarks were described based on a horizontal reference line (RL), which was based on the T1 S-N plane − 7 degrees, and transferred to the T2 tracings after cranial base superimposition, as described by Björk and Skieller [16]. The horizontal and vertical changes were measured parallel and perpendicular to the RL (Fig. 2). To determine the movements of the molars, maxillary and mandibular superimpositions were performed, as described by Björk and Skieller [15,16]. True mandibular rotation was measured as the angular change between RL and two mandibular fiduciary landmarks that were transferred from the T1 tracing to the T2 tracing after mandibular superimpositioning. Tooth movements were subtracted from the overall tooth movements (estimated using cranial base superimpositions) to estimate the displacement of the skeletal bases. Horizontally, an anterior change was recorded as positive, and a posterior change was recorded as negative. Vertically, a superior change was recorded as negative, and an inferior change was recorded as positive.

Replicate analyses of 16 patients were conducted to evaluate technical reliability. Of the 23 measurements, none showed statistically significant systematic differences. Method errors [23] $[\sqrt{(\sum deviations^2/2n)}]$ of the linear measures ranged between 0.114 mm and 0.270 mm, with gonion horizontal showing the largest random error. Angular measurement method errors ranged between 0.219° and 0.360°, with the gonial angle showing the greatest error.

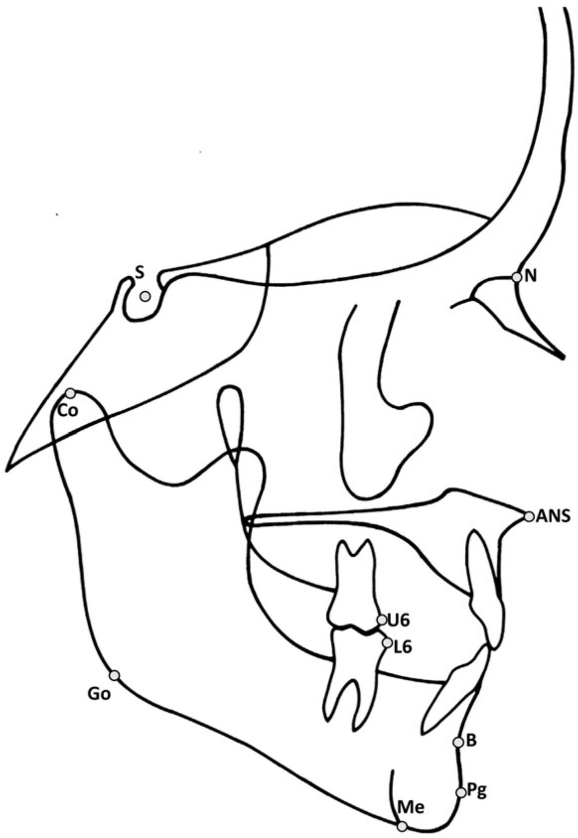

Fig. 1. Cephalometric landmarks digitized. ANS, anterior nasal spine; B, B-point; Co, condylion; Go, gonion; L6, mandible mesial molar; Me, menton; N, nasion; Pg, pogonion; S, sella; U6, maxillary mesial molar.

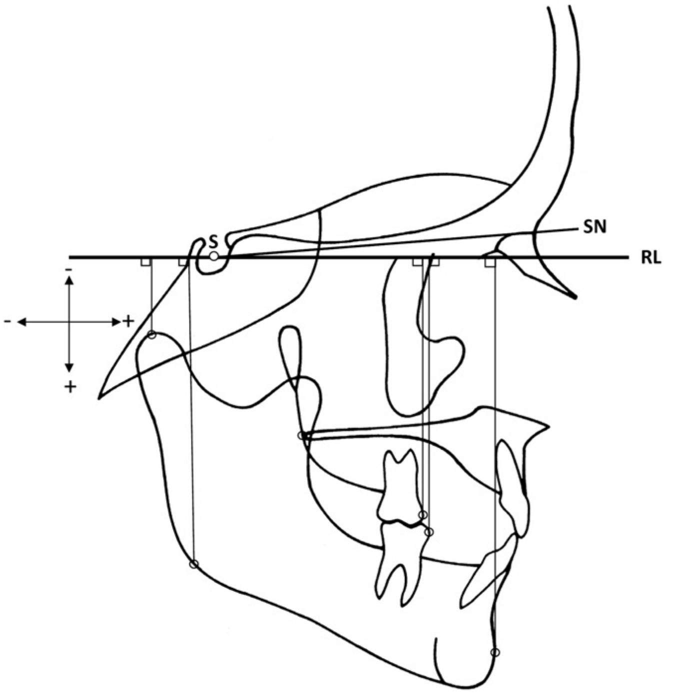

Fig. 2. Horizontal and vertical distances of the landmarks from the origin (S), evaluated parallel and perpendicular to reference line (RL), which was defined as S-N − 7°.

2.1. Statistical methods

The measurements were transferred to SPSS software (version 19.0; SPSS, Chicago, IL) for evaluation. The skewness and kurtosis statistics showed that the variables were not normally distributed. Group differences were evaluated using Mann-Whitney tests. To evaluate the effects of placing MSIs in one versus both jaws, group comparisons were performed both on the larger sample and the subsample (13) of patients who had MSIs placed only in the maxilla. Spearman rank-order correlations were used to evaluate the variables related to true rotation and anterior chin movements. A probability level of 0.05 was used to determine statistical significance.

3. Results and discussion

Mann-Whitney tests revealed significant ($P < 0.05$) group differences prior to treatment for three of the measures (Table 1). Compared with the untreated controls, the treated patients initially had smaller lower molar heights, smaller anterior facial heights (N-Me), and smaller gonial angles. When pretreatment measures of the 13 patients who only received maxillary MSIs were compared with their respective controls, only N-Me demonstrated significant group differences.

The treatment produced significant group differences (Table 2). Relative to the palatal plane, the upper molar in the treated group showed no significant changes, while it erupted significantly in the control group. Relative to the mandibular plane, the lower molar erupted twice as much in the treated patients than in the controls. The sella-nasion-pogonion (S-N-Pg) angle increased significantly ($P < 0.05$) more in the treated group than in the untreated group. While the treated group showed more true forward rotation than the control group, the difference was not statistically significant. The subsample of patients who only had maxillary MSIs also had significantly less upper molar eruption and decreases, rather than increases, of the ramus angle. The lower molar and S-N-Pg closely approached levels of statistical significance.

Based on the cranial base superimpositions, pogonion of both groups moved anteriorly; gonion underwent posterior movements in the control group (Table 3). Based on mandibular superimpositions, the treated patients had significantly greater posterior growth of condylion than the control group. The molars drifted anteriorly and gonion remodeled posteriorly, with no significant group differences. Only the subsample of patients with maxillary MSIs also had greater posterior movements of the condyle, but the difference was not statistically significant.

Based on cranial base superimpositions (Table 4), pogonion and gonion revealed more inferior movements in the treated patients, but the group differences were not statistically significant. The maxillary molar of the treated patients demonstrated no vertical change, whereas the molars in the control group erupted approximately 1.5 mm. In contrast, the mandibular molars of the treated erupted significantly more in the treated than in the control group

Table 1
Pretreatment linear and angular measurements of the treated patients (MSIs) and untreated (control) group

Measurements	Treated			Control			*P* value (18)	*P* value (13)
	Percentiles			Percentiles				
	25	50	75	25	50	75		
Linear								
U6⊥ ANS-PNS	17.6	21.1	22.3	20.0	21.8	24.2	0.097	0.270
L6⊥Go-Me	26.8	28.3	30.1	28.0	30.0	32.7	**0.040**	0.095
N-Me	107.4	113.8	117.4	115.9	121.1	128.1	**0.001**	**0.008**
ANS-Me	62.4	67.1	70.9	66.8	69.1	77.4	0.068	0.158
S-Go	67.7	70.0	72.5	69.0	71.9	75.4	0.152	0.158
Angular								
S-N-Pg	73.2	75.7	80.1	72.9	75.9	77.1	0.563	0.281
S-N-B	73.0	75.7	78.7	72.9	75.1	76.8	0.650	0.397
S-N/Go-Me	35.0	40.1	45.3	39.5	42.0	43.6	0.521	0.608
Co-Go-Me	123.9	128.7	131.0	127.6	131.2	132.9	**0.040**	0.061
S-Co-Go	88.0	93.9	95.5	89.7	91.2	93.8	0.279	0.343

Boldface indicates significance ($P < 0.05$).
Probabilities of two group differences (18 and 13 patients) are shown.
ANS, anterior nasal spine; B, B-point; Co, condylion; Go, gonion; L6, mandible mesial molar; Me, menton; MSIs, miniscrew implants; N, nasion; Pg, pogonion; S, sella; U6, maxillary mesial molar.

Table 2
Comparison of changes between treated patients and control group, with ACOVAR controlling for the pretreatment measures

Measurements	Treated			Control			*P* value (18)	*P* value (13)
	Percentiles			Percentiles				
	25	50	75	25	50	75		
Linear								
U6⊥ ANS-PNS	−0.9	0.3	1.2	0.8	**1.5**	1.9	**0.012**	**0.012**
L6⊥Go-Me	0.8	**2.0**	3.9	−0.3	**1.0**	1.4	**0.010**	0.168
N-Me	−0.2	**3.5**	5.6	1.4	**2.6**	4.9	0.938	0.362
ANS-Me	0.0	**1.6**	3.1	0.6	**1.5**	3.4	0.839	0.511
S-Go	1.3	**2.9**	5.2	0.5	**2.0**	3.4	0.389	0.511
Angular								
S-N-Pg	0.3	1.4	2.0	−0.3	0.9	1.4	**0.044**	0.057
S-N-B	0.3	1.3	1.8	−0.3	0.6	1.1	0.126	0.153
S-N/Go-Me	−1.5	−0.9	0.0	−1.2	0.3	1.0	0.239	0.050
Co-Go-Me	−1.9	−0.6	0.2	−2.6	−0.7	0.4	0.938	0.724
S-Co-Go	−1.3	−0.4	0.9	−0.4	0.8	1.9	0.111	**0.026**
True Rotation	−2.1	−0.8	0.9	−1.0	−0.4	0.3	0.542	0.169

Boldface indicates significant ($P < 0.05$) change over time.
Probabilities of two group differences (18 and 13 patients) are shown.
ACOVAR, analyses of covariance; ANS, anterior nasal spine; B, B-point; Co, condylion; Go, gonion; L6, mandible mesial molar; Me, menton; N, nasion; Pg, pogonion; S, sella; U6, maxillary mesial molar.

Table 3
Medians and interquantile ranges related to horizontal changes of the treated patients and the untreated control group (positive value = forward direction; negative value = backward direction)

Measurements	Treated			Control			P value (18)	P value (13)
	Percentiles			Percentiles				
	25	50	75	25	50	75		
Cranial base superimpositions								
Pg	0.2	2.2	3.9	−1.2	1.6	2.2	0.118	0.077
Go	−1.8	−0.1	1.7	−2.8	−1.4	0.4	0.118	0.069
Maxillary and mandibular superimpositions								
U6	−1.2	1.3	3.6	−0.4	0.6	0.8	0.372	0.898
Co	−4.5	−1.9	0.2	−1.7	−0.4	0.8	**0.047**	0.077
Go	−2.8	−2.0	−1.0	−2.2	−1.5	−1.1	0.355	0.778
L6	−2.1	0.8	2.6	−0.8	0.9	1.6	0.961	0.355

Boldface font indicates significant ($P < 0.05$) change over time between groups.
Probabilities of two group differences (18 and 13 patients) are shown.
Co, condylion; Go, gonion; L6, mandible mesial molar; Pg, pogonion; U6, maxillary mesial molar.

(2.2 mm versus 0.4 mm). Vertical remodeling at condylion and gonion showed no statistically significant group differences. The subsample of patients who only had maxillary MSIs also showed exactly the same differences as the larger sample.

Correlations between true rotation and anterior chin movements. In the treated patient group, true rotation demonstrated moderate negative correlations with the horizontal change of the Pg (-0.722; $P = 0.001$), changes of S-N-B (-0.699; $P = 0.001$), and changes of S-N-Pg (-0.690; $P = 0.002$). In contrast, the control group had no significant correlations between true rotation and anterior chin movements.

4. Discussion

Intrusion of molars with MSIs effectively controlled the vertical position of the upper molars. The upper molars did not have significant vertical movements over the 2.5 years of treatment, and during this time the molars of untreated controls erupted 1.5 mm. The amount of eruption that occurred in the control group was similar to, or slightly less than, amounts previously reported over comparable time periods [24–26]. In the present study, no set treatment protocol was used. The practitioner used clinical judgment to determine the location of MSI placement and whether or not MSIs were placed in the mandible. The upper molars were intruded in approximately half of the patients using forces delivered directly to the molars. MSIs have been previously used in hyperdivergent adults to hold or intrude the upper molars [17–20]. The other half of the patients had maxillary molar extrusion, which was probably due to inconsistent control of forces. For example, some patients went through some portion of their treatments without MSIs in the maxilla.

Although the upper molars were well controlled in the treated patients, the lower molars supraerupted; lower molars erupted vertically significantly more (1.8 mm) in the treated patients than in the controls (Fig. 3). Erverdi et al. [27] reported lower molar supraeruption in a 14-year-old girl with anterior open bite whose maxillary dentoalveolar segment was intruded using zygomatic anchorage. It is possible to control the vertical molars with MSIs in adults [17–20] and growing children [21]. The supereruption that occurred was not specifically related to the appliance system used. Previous studies of high-pull headgear have reported lower molar supereruption when the upper molars were intruded or held in place [28,29]. The supereruption that occurred compensated for the space created during growth that was not filled by the upper molar. Of the 18 treated patients, only 5 had MSIs placed in the lower jaw.

Vertical control of both the upper and lower molars is important if chin projection is a treatment goal. The most important skeletal treatment effect that occurred in the present study was the movement of the chin, which came forward more than expected. In the only other study evaluating the use of MSI in growing hyperdivergent patients, 2.4 mm or 2.1 degrees of chin projection were attained after 1.9 years of treatment [21]. MSI used in adults have produced an average of 1.6 degree increase in the SNB angle [17–21]. Unfortunately, none of these studies included untreated controls, making it difficult to determine what the treatment effects actually were. The effects on the chin in the present study were clearly better that those previously reported for high-pull headgears [24,25]. Although positive treatment effects on horizontal chin position were found in the present study, they probably would have been better if the vertical position of the lower molar had been better controlled (Fig. 3).

The anterior projection of the chin produced during treatment was due to true forward mandibular rotation. The individuals who had the greatest true rotation also had the greatest chin projection (Fig. 4); more than 50% of the variation in the horizontal movements of the chin was related to true rotation. The relationship between chin projection and true rotation has been previously demonstrated [11,14,30]. The individual cases reported by Björk and Skieller [15] described the greatest anterior chin movements and the greatest amounts of true forward rotation. Because mandibular rotation plays such an important role in chin projection, it must be

Table 4
Medians and interquantile ranges related to vertical changes of the treated patients and the untreated control group (positive value = forward direction; negative value = backward direction)

Measurements	Treated			Control			P value (18)	P value (13)
	Percentiles			Percentiles				
	25	50	75	25	50	75		
Cranial base superimpositions								
Pg	0.8	4.7	6.5	1.6	2.4	5.6	0.988	0.427
Go	1.3	2.8	5.2	0.3	2.0	3.1	0.308	0.457
Maxillary and mandibular superimpositions								
U6	−0.9	0.3	1.2	0.8	1.5	1.9	**0.003**	**0.004**
Co	−7.1	−4.2	−1.9	−5.4	−4.2	−1.3	0.606	0.700
Go	−2.2	−1.0	0.5	−3.2	−2.0	0.1	0.279	0.778
L6	−3.2	−2.2	−1.7	−1.3	−0.4	0.8	**<.001**	**0.007**

Boldface font indicates significant ($P < 0.05$) change over time between groups.
Probabilities of two group differences (18 and 13 patients) are shown.
Co, condylion; Go, gonion; L6, mandible mesial molar; Pg, pogonion; U6, maxillary mesial molar.

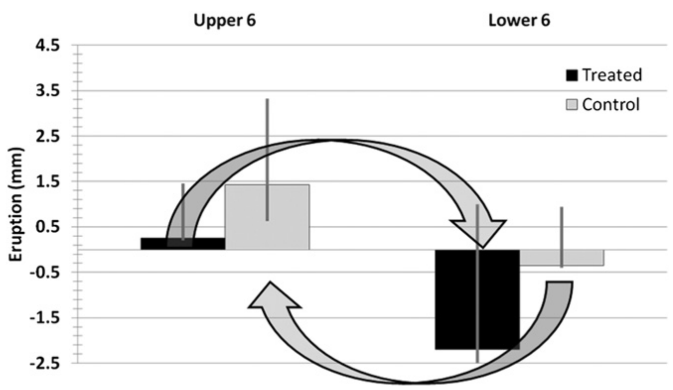

Fig. 3. Relationships between the eruption of the upper ($U6_{\perp}$ ANS-PNS) and lower ($L6_{\perp}$ Go-Me) molars in treated patients and untreated controls. The large bars show median values; the narrow bars show the 25th (lower limit) and 75th (upper limit) percentiles. ANS, anterior nasal spine; Go, gonion; L6, mandible mesial molar; Me, menton; PNS, posterior nasal spine; U6, maxillary mesial molar.

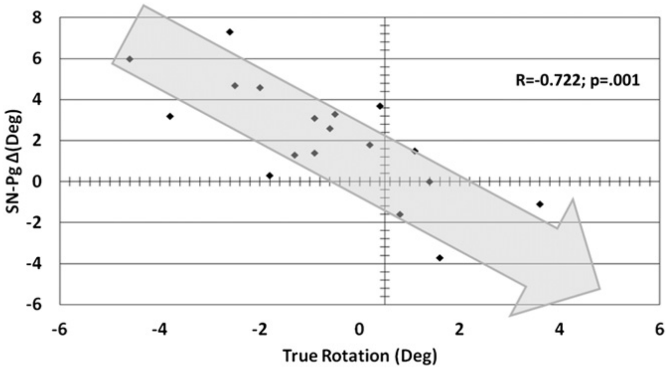

Fig. 4. Relationship between true mandibular rotation and SN-Pg changes during treatment. N, nasion; Pg, pogonion; S, sella.

addressed when attempting to treat retrognathic patients with convex profiles. Mandibular rotation can be controlled best by monitoring growth, intruding the upper teeth, and by controlling and/or intruding the lower teeth [21]. If the eruption of the lower molars in the present study had been better controlled, greater amounts of true rotation would probably have occurred, which, in turn, would have produced greater anterior chin movements (Fig. 5).

Although the true rotation and the mandibular plane angle decreased more in the treated patients, lower facial height and gonial angle did not reveal group differences. MSIs have been found to decrease lower facial height in adults [18,20,31]. Treatment could also have been further enhanced by reducing lower anterior facial height and the gonial angulation. These effects are important to improve the hyperdivergent patient's profile. Reductions in anterior facial height make it possible to relieve soft tissue tension, resulting in an increase in philtrum height and thus a more consonant lip arc at rest [32]. Reductions of the gonial angle help to reshape the mandible.

Although the intrusion of teeth is more stable than extrusion [33], the long-term stability of molar intrusion remains unclear, even though it has been suggested that the forces of occlusion might prevent the re-eruption of intruded molars and the relapse of open bite [34]. Using miniplates in adult patients, Sugawara et al. [35] reported relapse rates of 27.2% and 30.3% for the first and second molars, respectively, after the intrusion of mandibular molars, although no significant changes were found with respect to the mandibular plane angle and anterior facial height. Studies that have intruded the teeth of adults with MSIs have described both relapse after molar intrusion [31,36] and excellent stability 2 years posttreatment [19,32]. Relapse potential of adults and growing children may differ. Growth might be expected to be related to the functional adaptation of the musculature, which has been suggested to be an important factor determining stability [19]. Also, children require less absolute intrusion than adults due to their growth and associated eruption [21]. However, the long-term stability after treatment of requires further investigation.

This pilot study is not without limitations. The primary problem relates to the heterogeneity of the sample, combined with its small sample size. The fact that both males and females were included could not have affected the results because the treated patients were matched to the controls based on gender. Because extractions have been previously reported to have little or no effect on the vertical dimension [37,38], including both extraction and non-extraction patients also could not have had much of an effect on the outcome of the study. The fact that 13 MSIs were placed in the maxilla only and 5 were placed in both jaws is a real potential problem. Based on the comparisons of the patients who only had maxillary MSIs, this source of variation also does not appear to have affected the results. In fact, the results of this subsample suggest that they were less divergent than the larger sample, which is probably why they only had MSIs placed in the maxilla. Nevertheless, future studies are necessary to substantiate these pilot results.

5. Conclusions

Based on comparisons of Class II growing hyperdivergent patients and their matched controls, this study emphasizes the importance of forward rotation for correcting the anteroposterior position of the chin, as well as the importance of controlling the eruption of both the upper and lower molars. The following conclusions can be drawn:

1. Use of MSIs produced no overall vertical differences between the treated patients and the control group.
2. Upper molars were held in place in the treated patients, but the lower molars supererupted.
3. Compared with the control group, the treated patients' profiles improved only slightly, probably due to better chin projection.
4. Based on the relationships between true rotation and anterior chin movements, better chin projection could have been produced with greater rotation.

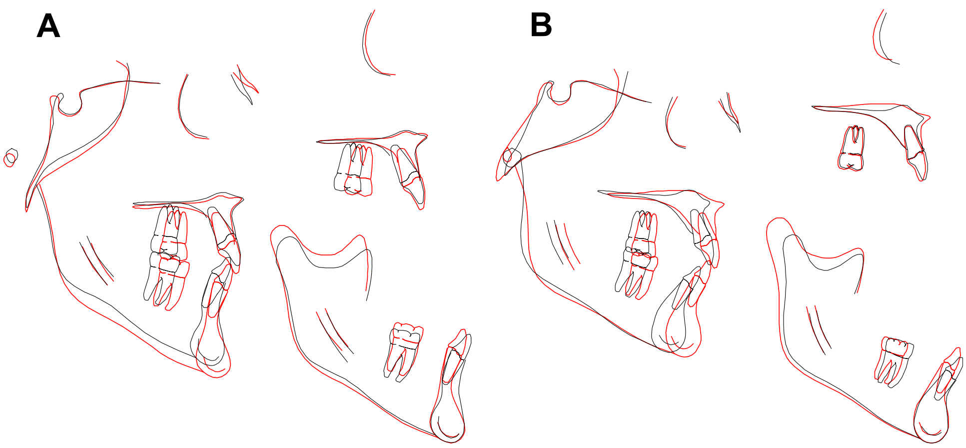

Fig. 5. Superimpositions of two treated patients with good amounts of condyle growth revealing differences in chin projection due to: (A) lack of vertical control of the lower molar; (B) control of the lower molar eruption.

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