How to achieve proper overbite—Lessons from natural dentoalveolar compensation

Jenny Zwei-Chieng Chang a,b, Wen-Chung Chang b, Kuang-Ho Chen c, Yunn-Jy Chen b,d, Yi-Jane Chen a,b, Eddie Hsiang-Hua Lai a,b, Chung-Chen Jane Yao a,b*

a Department of Orthodontics, School of Dentistry, National Taiwan University, Taipei, Taiwan
b Department of Dentistry, National Taiwan University Hospital, Taipei, Taiwan
c Central Taiwan University of Sciences and Technology, Taichung, Taiwan
d Department of Prosthodontics, School of Dentistry, National Taiwan University, Taipei, Taiwan

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KEYWORDS
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Abstract Background/purpose: To identify how dentoalveolar changes compensate for proper overbite in extreme vertical facial patterns. Materials and methods: Lateral cephalometric roentgenograms of preorthodontic adult patients with hyperdivergent (n = 49; SN-mandibular plane (MP) angle greater than 38 degrees) and hypodivergent (n = 38; SN-MP angle less than 28 degrees) skeletal patterns were selected. Skeletal-vertical (SV) variables were selected and summarized via stepwise regression methods and principal component analysis (PCA) in these two groups. Multiple regression analyses were performed to determine the relationship between overbite (OB) as the dependent variable and the PCA-derived SV, dental height (DH), and dental inclination (DI) as the independent variables. Results: Hyperdivergent patients have the tendency of anterior open bite. The natural dentoalveolar compensatory mechanism is manifested in shorter upper molar height and larger lower incisor height. Hypodivergent patients have no tendency of anterior deep bite. The shorter upper and lower incisor DHs and larger incisal inclination achieved dentoalveolar compensatory mechanism in these patients. Conclusion: For orthodontically closing the open bite, intruding upper posteriors and extruding lower anteriors are appropriate ways to simulate the natural occurring compensation. To eliminate deep bite in a low mandibular plane patient, intruding upper and lower anteriors and proclining anteriors will achieve good overbite. Imitating the natural dentoalveolar compensation by

* Corresponding author. Department of Orthodontics, School of Dentistry, National Taiwan University, Number 1, Chang-Te Street, Taipei 100, Taiwan.
E-mail address: janeyao@ntu.edu.tw (C.-C.J. Yao).

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Introduction

Patients with an extreme vertical skeletal relationship usually are predisposed to having an overbite problem.\(^1,\)\(^2\) It is commonly seen that hyperdivergent and/or long-faced patients exhibited anterior open bite, and hypodivergent and/or short-faced patients exhibited anterior deep bite. However, there are exceptions in that hyperdivergent patients may have normal incisal relationships in both horizontal and vertical directions, or even develop deep bite.

Dentoalveolar compensation is the key for maintaining normal inter-arch harmony under various jaw relationships. The compensatory mechanism is operated possibly via the surrounding soft tissues to coordinate the eruption and position of the teeth relative to their jaw bases, in order to establish and maintain a normal relationship between upper and lower dental arches for proper functions. If this compensation mechanism operates well, normal overbite could be obtained in hyperdivergent patients. By contrast, if the compensation is missing, progressive open bite can develop as the patient grows.

For orthodontic cases with extreme vertical problems with either open bite or deep bite, to obtain normal occlusion with satisfactory and stable results is quite challenging. However, naturally, there are people with extreme vertical skeletal pattern, presenting normal bite through good natural compensation. Therefore, studying the natural pattern of dentoalveolar compensation will provide logical guidelines for treating orthodontic cases to achieve appropriate overbite. In order to identify the compensation pattern, hyperdivergent and hypodivergent patients were selected for studying. Statistical methods were used to search for possible mechanisms of dentoalveolar compensation under extreme skeletal patterns in vertical direction.

Materials and methods

Lateral cephalometric roentgenograms of preorthodontic adult patients with hyperdivergent and hypodivergent skeletal patterns were selected from the database of the Orthodontic Department of National Taiwan University Hospital. The files were screened for adult patients with recorded angles greater than 38 degrees and less than or equal to 28 degrees.\(^3\) This criterion was set to one standard deviation (SD; 4.1) above or below the norm for Chinese patients (33.1 degrees) plus the measurement error 0.5 degree. Patients with any missing teeth, spaced anterior dentition, congenital facial or dental deformity, dental prostheses, or severe skeletal discrepancy in the horizontal direction were excluded from this study. According to the above selecting criteria, 49 adult patients with recorded angles greater than 38 degrees and 38 adult patients with recorded angles less than 26 degrees were collected. The hyperdivergent (SN-MP angle greater than 38 degrees; high angle) and hypodivergent (SN-MP angle less than 26 degrees; low angle) subjects were divided into three subgroups according to their overbite. The open bite subgroup consisted of subjects with overbite less than 0 mm. The normal bite subgroup consisted of subjects with overbite between 0 mm and 4 mm. The deep bite subgroup consisted of subjects with overbite greater than 4 mm. Hyperdivergent patients with open bite were considered to have poor dentoalveolar compensation. Hyperdivergent patients with normal overbite were considered to have good dentoalveolar compensation. Hyperdivergent patients with deep overbite were considered to have over dentoalveolar compensation. By contrast, hypodivergent patients with open bite were considered to have over dentoalveolar compensation. Hypodivergent patients with normal overbite were considered to have good dentoalveolar compensation. Hypodivergent patients with deep overbite were considered to have poor dentoalveolar compensation. The subject numbers and distributions of both facial types and their subgroups were tabulated in Table 1.

All lateral cephalograms were traced by the same observer. Landmarks were identified on the lateral cephalograms and lines constructed to obtain the data for skeletal–vertical (SV), dental height (DH), dental inclination (DI), and overbite (OB) characteristics. All variables were selected based on clinical interest. Definitions of the 33 measurements were listed in Table 2, and grouped according to the OB, SV, DH, and DI.

Twenty films were selected randomly, retraced, and remeasured on two separate occasions 2 weeks apart. All the measurements were made by the same observer. Dahlberg’s formula was applied to determine the errors between duplicate determinations. None of the linear measurements showed a discrepancy of greater than

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**Table 1** Description of study samples.

<table>
<thead>
<tr>
<th>Sample (n = 87)</th>
<th>Hyperdivergent (n = 49)</th>
<th>Hypodivergent (n = 38)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Open bite (n = 21): 42.85% (poor compensation)</td>
<td>Normal bite (n = 22): 44.89% (good compensation)</td>
<td></td>
</tr>
<tr>
<td>Deep bite (n = 6): 12.24% (over compensation)</td>
<td>Open bite (n = 1): 2.63% (over compensation)</td>
<td></td>
</tr>
<tr>
<td>Normal bite (n = 14): 36.84% (good compensation)</td>
<td>Deep bite (n = 23): 60.53% (poor compensation)</td>
<td></td>
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</tbody>
</table>

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0.5 mm and none of the angular measurements showed a discrepancy of greater than 0.5 degrees on repeated measurements. Thus, intra-observer errors could be neglected.

**Statistical analysis**

Standardization was performed to reduce the heterogeneity of measurement units: angle degree, length, and ratio. Each variable apart from the endpoint, the OB, was divided by the SD of the studied subjects.

One of the study focuses was the SV characteristic, which contained 22 measurements. To avoid redundancy among the various variables, stepwise regression and stepwise logistic regression procedures were performed in the first place to obtain the smallest possible set of significant SV parameters that would be able to explain a
significant amount in the OB variable at the $P = 0.05$ significance level. Because many of these SV variables were inter-related, principal component analysis (PCA) was performed afterwards to summarize the SV variables selected from the stepwise regression and stepwise logistic procedures into new variables that would represent the same SV characteristics yet were noncorrelated to each other.

Finally, several multiple regression analyses were performed to determine the relationship between OB as the dependent variable and the new SV, DH, and DI as the independent variables. Interaction effect between SV and DH, or SV or DI, was tested using SV $\times$ DH or SV $\times$ DI added into the regression models to see if the new interaction variable replaced the individual factors. A $P$ value $<0.15$ was used to set the threshold while running the regression model, and $P \leq 0.05$ was considered statistically significant.

All statistical analyses were performed using the SAS statistical software package (SAS Institute Inc., Cary, NC, USA).

**Results**

To reduce the heterogeneity of measurement units (angle degree, length, and ratio), standardization was performed. Each variable was divided by the SD of the studied subjects except for the OB, the reading for the end result of compensation. Furthermore, in order to avoid redundancy among the various variables, stepwise regression and stepwise logistic regression were performed first to screen for significant skeletal measurements which can affect the amount of overbite. Among the hyperdivergent subjects, a total of eight variables was associated with the overbite or open bite (A-Gn, N-Go-Gn, and PFH/AFH by stepwise regression for overbite; OP-MP, FH-SGn, Ar-Go, UAFH/LAFH, and A-Ar-Gn by stepwise logistic regression for OB $<0$). When deep overbite (OB $>4$) was used as dependent variable, four characteristic SV variables including FH-SGn, ArGo-FH, A-Gn, and N-Go-Ar were identified from the hypodivergent group by the stepwise logistic regression procedure. Subsequently, PCA was performed to remove the intercorrelations between these SVs. PCA procured five principal components for those eight SV variables in the hyperdivergent group. The 1st principal component alone explained 99.05% of the variance. Thus, one single new variable, Long SV, was found to represent the performance of all skeletal variables in the vertical direction for hyperdivergent patients:

$$\text{Long SV} = 0.354536 \times (A-Gn) + 0.354977 \times (N-Go-Gn) + 0.354328 \times (PFH/AFH) + 0.350425 \times (OP-MP) + 0.354651 \times (FH-SGn) + 0.352491 \times (Ar-Go) + 0.352441 \times (UAFH/LAFH) + 0.354532 \times (A-Ar-Gn).$$

Four principal components were procured for those four SV variables in the hypodivergent group. The 1st principal component alone explained 99.52% of the variance. Thus, the new variable, Short SV, was found to represent the performance of all skeletal variables in the vertical direction for hypodivergent patients:

$$\text{Short SV} = 0.500924 \times (FH-SGn) + 0.500251 \times (ArGo-FH) + 0.500423 \times (A-Gn) + 0.498397 \times (N-Go-Ar).$$

Thus, this simplified the further analysis screening for the possible compensatory factors with one representative variable (Long SV or Short SV) from all SV cephalometric measurements in either hyper- or hypodivergent groups.

**The relationship between the SV characteristic or DH or DI and OB in the hyperdivergent group**

First, a regression equation was obtained for the influence of Long SV on overbite: $OB = -10.18 \times (\text{Long SV}) + 29.01 (P = 0.0024)$.

This revealed that the larger the facial divergency in the hyperdivergent group, the smaller the anterior overbite detected. As a result, open bite occurred more frequently in subjects with the long-face type. When the DH variable was added individually along with Long SV into the regression, upper molar height and lower incisal height were found to have negative and positive influence on the OB, respectively (Table 3). The deeper overbite occurred with smaller UM-PP, which implied that the upper first molar DH played an important role in the compensatory mechanism for overbite in subjects with the long-face type. On the contrary, the longer lower incisal height in the more

| Table 3 | Equations of overbite when different variables were tested in the hyperdivergent group. |
|---------|---------------------------------|---------------------------------|
| Dependent variables | Intercepts | Independent variables | P |
| OB = | | Long SV | DH | Interactions |
| +29.01 | -10.18 | -1.26 (UM-PP) | 0.0024 |
| +10.73 | 0 | +2.38 (LIE-MP) | 0.0020 |
| +49.86 | -25.76 | +2.23 (LM-MP) | <0.0001 |
| +8.44 | 0 | +0 (UM-PP) | <0.0001 |
| +45.22 | -24.15 | -35 (Long SV $\times$ UM-PP) | 0.0015 |

Equations from multiple regression analyses to determine the relationship between overbite (OB) as the dependent variable and the independent variables including one skeletal vertical (SV), four dental height (DH) variables, and eight dental inclination (DI) variables. A $P$ value $<0.05$ was considered statistically significant. Bold characters indicate clinically significant independent variables. Variables were marked a, b, c corresponding to the P values marked accordingly in each equation.
hyperdivergent group would be needed for obtaining the deeper OB. However, upper incisal height and lower molar height did not contribute significantly for establishing OB. When interactions were considered among the variables representing SV and DH, the synergistic effects were identified. The larger the facial divergency, the stronger the compensatory mechanism accounted for in the upper first molar DH because the new variable, the interaction effect between the SV characteristic and the upper first molar DH (Long SV × UM-PP), was entered in the regression as the independent variable to replace both Long SV and UM-PP. By contrast, lower incisal height remained in the equation while the interaction effect between Long SV and LIE-MP was tested in the regression.

When Long SV, anterior DHs of maxilla and mandible (UIE-PP, LIE-MP), and the interactions between these three variables were considered, the equation became: OB = 49.85 ÷ 25.76 (Long SV) + 2.38 (LIE-MP). The compensatory mechanism of lower incisor DH was obviously stronger than upper incisor DH.

When Long SV, posterior DHs (UM-PP, LM-MP), and the interactions between these three variables were evaluated, the equation became: OB = 8.4 ÷ 0.35(Long SV × UM-PP). The compensatory mechanism upper molar DH was obviously stronger than lower molar DH.

As for the relationship between DI and OB in the hyperdivergent group, all variables representing dental inclination were excluded from the regression models. No compensatory mechanism of dental inclination was found for overbite in hyperdivergent patients.

The relationship between the SV characteristic or DH or DI and OB in the hypodivergent group

There was no statistical significance between the dependent variable OB and the independent skeletal variable in the hypodivergent group (Short SV). Facial divergency and anterior overbite were not associated in the hypodivergent group. Therefore, there was no deep bite tendency in subjects with the short-face type statistically.

When the DH variable was added independently into the regression, upper incisor DH (UIE-PP) and lower incisor DH (LIE-MP) were found to have positive influence on the OB (Table 4). No statistical significances between overbite and upper and lower first molar DHs were found.

When Short SV, anterior DHs of maxilla and mandible (UIE-PP, LIE-MP), and the interactions between these three variables were considered, the equation became: OB = –5.52 ÷ 1.57 (UIE-PP). The compensatory mechanism of upper incisor DH was obvious. When Short SV, posterior DHs (UM-PP, LM-MP), and the interactions between these three variables were evaluated, all variables were excluded from the equation. The compensatory mechanism of posterior DHs was not found.

When the compensatory mechanism of maxillary DHs was considered, Short SV, UIE-PP, UM-PP, Short SV × UIE-PP, Short SV × UM-PP, UIE-PP × UM-PP, Short SV × UIE-PP × UM-PP were tested in the regression as the independent variables. The equation obtained was: OB = –9.35 ÷ 3.26 (UIE-PP) – 0.07 (Short SV × UIE-PP × UM-PP). Upper incisor DH exhibited a stronger compensatory mechanism than upper first molar in hypodivergent patients. When the compensatory mechanism of mandibular DHs was considered among Short SV, LIE-MP, LM-MP, and the interactions between these three variables, the equation acquired was: OB = –20.91 ÷ 4.00 × (LIE-MP) – 0.07 × (Short SV × LIE-PP × LM-MP). The lower incisor DH displayed a stronger compensatory mechanism than the lower first molar.

When the DI variable was added independently into the regression, inclination of the upper and lower incisors was negatively correlated to the overbite (Table 4). The more proclined upper or lower incisal axis correlated with shallower overbite. By the same token, the inter-incisal angle appeared to be positively correlated to the overbite in the short-face subjects. The more obtuse inter-incisal angle, the deeper the overbite.

Table 4  Equations of overbite when different variables were tested in the hypodivergent group.

<table>
<thead>
<tr>
<th>Dependent variables</th>
<th>Intercepts</th>
<th>Independent variables</th>
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<tbody>
<tr>
<td></td>
<td></td>
<td>Short SV DH or DI Interactions P</td>
</tr>
<tr>
<td>OB =</td>
<td>–5.52</td>
<td>0 1.57 (UIE-PP) Upper Dhs –0.07 0.0015</td>
</tr>
<tr>
<td></td>
<td>–7.91</td>
<td>1.48 (LIE-MP) (Short SV × UIE-PP) 0.0203</td>
</tr>
<tr>
<td></td>
<td>–9.35</td>
<td>3.26 (UIE-PP) (Short SV × UIE-PP × UM-PP) 0.0013a</td>
</tr>
<tr>
<td></td>
<td>–20.9</td>
<td>4.00 (LIE-MP) (Short SV × UIE-PP × LM-MP) 0.0476b</td>
</tr>
<tr>
<td></td>
<td>+26.26</td>
<td>–1.74 (U1-PP) Lower Dhs –0.07 0.0166a</td>
</tr>
<tr>
<td></td>
<td>+16.26</td>
<td>–0.97 (U6-PP) (Short SV × UIE-PP × UM-PP) 0.0968b</td>
</tr>
<tr>
<td></td>
<td>+20.69</td>
<td>–1.24 (L1-MP)</td>
</tr>
<tr>
<td></td>
<td>–10.61</td>
<td>+1.81 (U1-L1)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.1059</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.0033</td>
</tr>
<tr>
<td></td>
<td></td>
<td>&lt;0.0001</td>
</tr>
</tbody>
</table>

Equations from multiple regression analyses to determine the relationship between overbite (OB) as the dependent variable and the independent variables including one skeletal-vertical (SV), four dental height (DH) variables, and eight dental inclination (DI) variables. A P value ≤0.05 was considered statistically significant. Bold characters indicate clinically significant independent variables. Variables were marked a, and b corresponding to the P values marked accordingly in each equation.

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The upper and lower molar inclination was considered not significantly correlated to overbite in the hypodivergent group. Also, the inter-molar angle was considered not correlated to the overbite.

Discussion

During the statistical analysis, initially all the subjects were divided into groups according to their OB values. Afterwards, ANOVA and Pearson correlation analysis were utilized to compare the significance (mean, SD, correlation coefficient) between the groups. However, no significant results were found. There are two possible explanations. One is that individual variations were overlooked. For example, it is not fair to compare the mandibular length or DH of a person with an extremely large face to those of a person with a tiny face. The other is that there were too many variables and many of these variables were inter-related to each other. For example, correlations between the SV measurements may lead to confusion when attempting to analyze the data.

Facing this multifactorial situation and different units of the variables, we chose to standardize all the measurements in the first step for the statistics. Each measurement was divided by its own SD. There were two advantages from performing this step: one was to eliminate the variation between different individuals; the other was to eliminate the variation between different measurements in the same subjects. The next step was the stepwise selection of SV variables to reduce the redundancy of these variables. Only the utmost important and distinguishable variables were selected. Afterwards, PCA was performed to remove the intercorrelations between these variables. The cumulative percentages of the 1st principal components were as high as 99.05% for the hyperdivergent subjects and 99.52% for the hypodivergent subjects. Thus two new variables, Long SV and Short SV, were obtained by PCA to represent the performance of all skeletal variables in the vertical direction for hyperdivergent and hypodivergent groups, respectively. Finally, multiple regression analyses were used to test which of the DH and DI measurements and/or SV characteristics made a significant contribution to the estimation of overbite. The result of this study reveals that the dentoalveolar compensatory mechanism is mainly located at the upper molar DH and lower incisor DH, but not at the DI in hyperdivergent patients. This natural compensatory mechanism prevents the occurrence of anterior open bite by depressing upper molar DH and increasing lower incisor DH. Thus, the treatment plan for a patient presenting a hyperdivergent face along with anterior open bite malocclusion should aim at inhibition of upper molar incisal movement and/or intrusion of upper molars and extruding lower incisors in order to simulate the natural compensation, which possibly leads to a more stable treatment result (Fig. 1A). Appliances such as posterior bite blocks,9 high pull headgear,10 vertical chin cap,11 and temporary anchorage devices12 are all feasible methods to control molar DHs. Anterior vertical elastics with/without Multi-loop Edgewise Archwire (MEAW) techniques help to increase incisor dental heights.13,14 However, the vertical movement of the upper incisor should be carefully controlled to maintain a pleasing relationship with the lip and gum lines. Accordingly, intermaxillaries applied to molars must be avoided to maintain the aesthetics and treatment stability. In more extreme situations, such as severe skeletal open bite problems, one should resort to a combined orthodontic—surgical approach.15,16

By contrast, the dentoalveolar compensatory mechanism is located at incisor DHs and incisor DIs in patients with a hypodivergent face. Thus, for a patient presenting a hypodivergent face along with deep bite, the orthodontic treatment plan should aim to intrude and procline incisors to provide favorable inter-incisal relationships simulating the natural compensation and achieving good overbite (Fig. 1B). All teeth banded and bonded including second molars to level occlusal curves is desirable. Nonextraction approaches are favored in these skeletal patterns.17 However, when extraction treatment is the only plan for subjects with extremely severe crowded teeth, the utmost care should be taken to avoid uprighting incisors.

From these patients with extreme vertical patterns and exhibiting different degrees of compensations, we learned:
Hyperdivergent patients have the tendency of anterior open bite. The natural dentoalveolar compensatory mechanism is located mainly at upper molar and lower incisor DH. Favorable overbite occurs with shorter upper molar height and larger lower incisor height. Hypodivergent patients have no tendency of anterior deep bite. The dentoalveolar compensatory mechanism is located mainly at upper and lower incisor DHs and DI. Favorable overbite occurs with the shorter upper and lower incisor DHs, and larger incisal inclinations, i.e., with more proclined upper and lower incisors.

These naturally compensated patterns can provide good guidelines for treating orthodontic patients with SV problems to obtain proper overbite.

Acknowledgments

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References


Figure 1  (A) To treat a hyperdivergent patient, intrusion of upper molars and extrusion of lower incisors (arrows) can be performed to mimic the natural compensation for avoiding open bite. (B) In a hypodivergent patient, intrusion and proclination of upper and lower incisors (arrows) can solve the deep bite as the natural compensation does.