Introduction

A slight skeletal and soft tissue facial asymmetry can be found in normal subjects and even in those with esthetically pleasing faces. In general, very few healthy young subjects show statistically significant mandibular asymmetry of any clinical importance. However, patients with evident facial asymmetry can have reduced satisfaction with their facial appearance and thus a higher motivation to undergo orthodontic treatment to improve esthetics and occlusion. Among orthodontic patients with facial asymmetry (34%), the prevalence of chin deviation was as high as 74%. However, little research has been carried out on the mechanisms of chin deviation and the association between chin deviation and asymmetry in other parts of the facial skeleton during skeletal development.

Asymmetry in the area of the craniofacial skeleton can be found in 3 dimensions: sagittal, vertical, and transverse. Growth of the cranium, maxilla, and mandible are closely related. If not compensated by other areas, the asymmetric growth and development in any craniofacial skeleton may result in the deviation of the chin from the middle of the mandible. Therefore, patients with apparent chin deviation may also have marked asymmetry in other parts of the facial skeleton.
skeleton.\textsuperscript{14,15} In addition, differences in the size of human mandibular halves are also well documented,\textsuperscript{16,17} showing that it is strongly dependent on the muscular balance\textsuperscript{18–20} and unilateral overgrowth\textsuperscript{21–23} or undergrowth of the mandible,\textsuperscript{24–26} both of which might also be related to previous infections or injury to the condylar region and lateral occlusion.\textsuperscript{27–29} Asymmetry in mandibular halves usually results in a shift of the chin, and chin deviation can result from occlusal interferences and subsequent mandibular functional displacement. According to Schmid et al,\textsuperscript{28} 70\% of patients with facial asymmetry and chin deviation presented structural and displacement asymmetry, while only 10\% showed pure displacement asymmetry.

The purpose of this study was to investigate the facial skeletal characteristics of patients with a deviated chin position. Clarifying the association between the severity of facial skeletal asymmetry and chin deviation can allow the mechanism of chin deviation to be determined and to develop more thorough clinical approaches to diagnosing facial asymmetry and planning treatment.

\section*{Methods}

Twenty-five subjects over the age of 15 years diagnosed with chin deviation of more than 2\,mm were selected from patients who started orthodontic treatment at Taipei Veterans General Hospital between 2000 and 2001. Data were collected on 14 males aged 19–33 years (mean age, 24.1 years), and 11 females aged 15–33 years (mean age, 22 years). None of the subjects had congenital craniofacial anomalies, previous orthodontic treatment, facial trauma, or any temporomandibular dysfunction history.

Patients were examined by an experienced orthodontist in the upright sitting posture with teeth in centric relation and lips in repose. The facial midline (the line connecting the soft tissue glabella and subnasal) was identified, then the direction and severity of chin deviation and Angle’s classification of malocclusion of each patient were recorded. Following this, a 2-cm long iron wire was fixed with tape to the soft tissue of the menton (ME) to calculate the radiograph magnification and to identify the ME on radiogram.

Posteroanterior (PA) cephalograms of patients were then traced on acetate paper, and 15 landmarks located. All the tracings and landmarks were scanned and digitized (Figure 1). The line passing through the crista-galli of the ethmoid (CG) and anterior nasal spine (ANS) was used as the vertical reference plane (y-axis), and a line perpendicular to this plane through CG represented the horizontal plane (x-axis). Using these landmarks in an x–y coordinate system, the skeletal facial asymmetry was quantified using the software Viewbox Version 2.6 (dHAL Software, Kifissia, Greece). The direction of ME deviation was assigned 0 when it was located left or 1 when it was located right of the y-axis. The distance of ME from the y-axis was the amount of chin deviation (MEDEV) and measured as an absolute value. Gonial angle, mandibular body length, ramus height, mandibular effective length, and perpendicular distance of lateral points from the x-axis and the y-axis.

![Figure 1. Landmarks. Median points (on the midsagittal plane): 1 = CG (crista-galli of the ethmoid); 2 = ANS (anterior nasal spine); 3 = ME (menton, located by projecting the mental protuberance on the lower mandibular border). Lateral points: 4 and 5 = ZFL and ZFR (zygomaticofrontal suture left and right, points at the medial margin of the zygomaticofrontal suture); 6 and 7 = NCL and NCR (nasal cavity at the widest point left and right); 8 and 9 = JL and JR (jugale left and right, the intersection of the lateral contour of the maxillary alveolar process and the lower contour of the maxillaryzygomatic process of the maxilla); 10 and 11 = ZL and ZR (zygion left and right, points at the most lateral border of the center of the zygomatic arch); 12 and 13 = COL and COR (condylion left and right, most superior points of the condylar head); 14 and 15 = AGNL and AGNR (antegonion left and right, highest points in the antegonial notch).]
were measured. The differences and absolute differences between paired left and right measurements were calculated.

To test for repeatability, 10 patients and their cephalograms were randomly selected. Clinical examinations, tracings, and measurements of each cephalogram were repeated by the same orthodontist 1 week later. Measurement errors were determined by intra-class correlation coefficient, \( r_i \). There was no statistical difference between measurements.

To analyze the symmetry of the facial skeleton in patients with chin deviation, the differences between vertical or horizontal distance of each paired lateral point to the x- or y-axis were examined with \( r_i \). If the differences were not statistically significant and the lower limit of the 95% confidence interval of \( r \) was \( >0.75 \), then the left and right distances were considered to be equal and the paired points symmetric, otherwise the paired points were considered asymmetric.

The following was done to investigate which skeletal landmarks were associated with the amount of chin deviation: MEDEV was assigned as dependent variable \( Y \) and the absolute differences of left and right measurements as independent variable \( X \). The correlation coefficient between independent and dependent factors was tested by bivariate correlation and significance (\( p<0.05 \)) and further analyzed by multiple regression.

The following was done to analyze which facial skeletal landmarks were associated with the direction of chin deviation: direction of chin deviation was used as dependent variable \( Y \) and the difference between left and right measurements as independent variable \( X \). An independent sample \( t \) test was used to examine the association between direction of chin deviation and each of the variables. Significances (\( p<0.05 \)) were further analyzed by logistic regression. The statistical analyses were performed using SPSS version 10.0 (SPSS Inc., Chicago, IL, USA).

**Results**

This study included 25 patients with chin deviation of more than 2 mm. Ten (40%) subjects had a chin deviation of between 2 and 4 mm; 7 (28%) between 4 and 6 mm; 2 (8%) between 6 and 8 mm; and 6 (24%) between 8 and 10 mm. Seventeen subjects (68%) showed chin deviation to the left side and 8 subjects (32%) to the right side. The numbers of subjects presenting Angle Class I, II, and III malocclusion were 5 (20%), 3 (12%), and 17 (68%), respectively.

The distances between left and right lateral points to the x- or y-axis were compared for the analysis of symmetry of facial skeleton in patients with chin deviation. Gonial angle, ramus height, and vertical distances from all lateral points to the x-axis were symmetrical except for the zygomaticofrontal suture (ZF) and zygonion. However, mandibular body length and effective length, horizontal distances from all lateral points to the y-axis, and vertical distance from ZF and zygonion to the x-axis, showed a low grade of symmetry (Table 1).

Using bivariate correlation, it was found that the absolute left and right difference of antegonion (AGN) to the y-axis (AHAGN), ZF to the x-axis (AVZF), ramus height, and mandibular effective length showed significant correlations with the amount of chin deviation. After further analysis by multiple regression analysis, it was found that the amount of chin deviation was significantly associated with the absolute horizontal difference between left and right AGN to the y-axis and the absolute vertical difference between left and right ZF to the x-axis (Table 2).

\[
y = 2.693 + 0.575 \times 1 - 0.427 \times 2 \quad (R^2 = 0.747)
\]

where \( y = \) MEDEV (mm); \( 1 = \) AHAGN (mm); \( 2 = \) AVZF (mm).

The difference between left and right gonial angle, mandibular body length and effective length, ramus height, AGN to the y-axis, and zygonion to the x-axis were significantly associated with the direction of chin deviation. Since mandibular body length and effective length were highly associated in terms of Pearson’s correlation (\( r = 0.894 \)), only mandibular effective length was included in logistic regression analysis with the above factors. The results showed that for every 1-mm distance of left mandibular effective length longer than that of the right side, the possibility of chin deviation to the right side was 2.2 fold of that to the left side (Table 3).

**Discussion**

According to a criterion used previously, chin deviation of more than 2 mm was considered asymmetric.9,31,32 In this study, the amount of chin deviation was determined clinically and in the range of 2 to 10 mm. The ratio of chin deviation to the left side and to the right side was about 2 to 1 in this study. The prevalence of chin deviation to the left side over the right side has been reported previously.9,32,33 In our study sample, the horizontal or vertical distances from right landmarks to the y- or x-axis were larger.
than those from the left landmarks, which indicated that the horizontal and vertical dimensions of the right side of the face were longer than those of the left side of the face and might contribute to the more frequent deviation of the chin to the left side.

Sixty-eight percent of our asymmetric subjects had Class III malocclusion. Many investigators have also reported facial asymmetry in subjects with skeletal Class III deformity.2,21,23,32 Given the fact that mandibular prognathism was predominant in patients

Table 1. Symmetry of facial skeleton landmarks in patients with chin deviation

<table>
<thead>
<tr>
<th>Variable</th>
<th>( r_i ) between left and right measurements</th>
<th>Lower confidence limit of ( r_i )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gonial angle</td>
<td>0.9583</td>
<td>0.7568</td>
</tr>
<tr>
<td>Mandibular body length</td>
<td>0.3599</td>
<td>-0.3735*</td>
</tr>
<tr>
<td>Ramus height</td>
<td>0.9562</td>
<td>0.9040</td>
</tr>
<tr>
<td>Mandibular effective length</td>
<td>0.9109</td>
<td>0.7107*</td>
</tr>
<tr>
<td>HZF</td>
<td>0.7844</td>
<td>0.5208*</td>
</tr>
<tr>
<td>HZ</td>
<td>0.9277</td>
<td>0.2785*</td>
</tr>
<tr>
<td>HNC</td>
<td>0.6080</td>
<td>-0.1490*</td>
</tr>
<tr>
<td>HJ</td>
<td>0.8709</td>
<td>0.2963*</td>
</tr>
<tr>
<td>HCO</td>
<td>0.8342</td>
<td>0.0153*</td>
</tr>
<tr>
<td>HAGN</td>
<td>-0.4459</td>
<td>-2.5547*</td>
</tr>
<tr>
<td>VZF</td>
<td>0.8700</td>
<td>0.6969*</td>
</tr>
<tr>
<td>VZ</td>
<td>0.7301</td>
<td>0.3964*</td>
</tr>
<tr>
<td>VNC</td>
<td>0.9186</td>
<td>0.8618</td>
</tr>
<tr>
<td>VJ</td>
<td>0.9449</td>
<td>0.8599</td>
</tr>
<tr>
<td>VCO</td>
<td>0.9325</td>
<td>0.8520</td>
</tr>
<tr>
<td>VAGN</td>
<td>0.9265</td>
<td>0.8376</td>
</tr>
</tbody>
</table>

* \( p < 0.05 \) for asymmetry between left and right variables. \( r_i \) = intraclass correlation coefficient; HZF = difference between horizontal distances of paired zygomaticofrontal suture points to the y-axis; HZ = difference between horizontal distances of paired zygonion points to the y-axis; HNC = difference between horizontal distances of paired nasal cavity points to the y-axis; HJ = difference between horizontal distances of paired jugale points to the y-axis; HCO = difference between horizontal distances of paired condylii points to the y-axis; HAGN = difference between horizontal distances of paired antegoniennes to the y-axis; VZF = difference between vertical distances of paired zygomaticofrontal sutures to the x-axis; VZ = difference between vertical distances of paired zygonion points to the x-axis; VNC = difference between vertical distances of paired nasal cavity points to the x-axis; VJ = difference between vertical distances of paired jugale points to the x-axis; VCO = difference between vertical distances of paired condylii points to the x-axis; VAGN = difference between vertical distances of paired antegoniennes to the x-axis.

Table 2. Factors associated with the amount of chin deviation analyzed by multiple regression

<table>
<thead>
<tr>
<th>Dependent variable</th>
<th>Step</th>
<th>Independent variable</th>
<th>B value</th>
<th>R² increase</th>
<th>F</th>
<th>p</th>
<th>Odds value</th>
<th>Beta value</th>
</tr>
</thead>
<tbody>
<tr>
<td>MEDEV</td>
<td>1</td>
<td>AHAGN</td>
<td>0.812</td>
<td>0.659</td>
<td>44.433</td>
<td>0.000</td>
<td>0.610</td>
<td>0.812</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>AHAGN</td>
<td>0.864</td>
<td>0.747</td>
<td>32.532</td>
<td>0.000</td>
<td>0.575</td>
<td>0.766</td>
</tr>
<tr>
<td></td>
<td></td>
<td>AVZF</td>
<td>-0.427</td>
<td>-0.301</td>
<td>0.011</td>
<td>0.909</td>
<td>-0.427</td>
<td>-0.301</td>
</tr>
</tbody>
</table>

MEDEV = 2.693 \times AHAGN – 0.427 \times AVZF. Dependent variable: MEDEV (mm) = amount of chin deviation. Independent variables included in analysis: AHAGN (mm) = absolute horizontal difference between left and right antegoniennes to y-axis; AVZF (mm) = absolute vertical difference between left and right zygomaticofrontal sutures to x-axis; ARH (mm) = absolute difference between left and right ramus heights; AEF (mm) = absolute difference between left and right effective lengths.

Table 3. Factors associated with the direction of chin deviation analyzed by logistic regression

<table>
<thead>
<tr>
<th>Independent factor</th>
<th>B value</th>
<th>Wald</th>
<th>p</th>
<th>Exp(B)</th>
<th>R²</th>
<th>95% CI for Exp(B)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Lower            Upper</td>
</tr>
<tr>
<td>DEF</td>
<td>0.754</td>
<td>4.883</td>
<td>0.027</td>
<td>2.215</td>
<td>0.806</td>
<td>1.089             4.149</td>
</tr>
<tr>
<td>Constant</td>
<td>0.238</td>
<td>0.082</td>
<td>0.774</td>
<td>1.269</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Dependent variable: direction of chin deviation, where “0” = to left and “1” = to right. Independent variables included in analysis: DGO = difference between left and right gonial angles; DLAGN = difference between left and right antegoniennes to y-axis; DNS = difference between left and right zygonion points to x-axis; DRH = difference between left and right ramus heights; DEF = difference between left and right effective lengths. All the differences were calculated as left side value minus right side value.
with Class III malocclusion in Taiwan,34–36 we suspected that mandibular hyperplasia or condylar overgrowth may increase the risk of asymmetric growth of the mandible and result in chin deviation.

In this study, patients with obvious chin deviation also had significant horizontal asymmetry in paired skeletal landmarks in the upper, middle, and lower face. Bilateral mandibular body length and effective length were also asymmetric. However, except at the ZF and zygonion, there was no significant vertical asymmetry between paired landmarks. These data suggested that chin deviation might be associated with asymmetric horizontal dimensions of the right and left sides of the face. Occlusal cant in the frontal plane has also been suggested to be a reflection of facial asymmetry.37 Dentoalveolar asymmetry in children might lead to a further progressive change that influences the condyle-fossa relationship, leading to a deviation of the mandible.38 Therefore, imbalance in the vertical growth between the right face and left face might still be associated with chin deviation in some cases.

However, combining the absolute horizontal difference of AGN and the vertical difference of ZF explained 74.7% of chin deviation. This suggested that vertical asymmetry between the right and left halves of the upper face might also have an influence on chin deviation. There were a few patients with obvious chin deviation in our study who also presented with a significant vertical asymmetry between the right and left sides of the face. Occlusal cant in the frontal plane has also been suggested to be a reflection of facial asymmetry.37 Dentoalveolar asymmetry in children might lead to a further progressive change that influences the condyle-fossa relationship, leading to a deviation of the mandible.38 Therefore, imbalance in the vertical growth between the right face and left face might still be associated with chin deviation in some cases.

Because of the limitations of PA cephalograms, asymmetry in facial depth could not be measured in this study. Theoretically, asymmetry in facial depth might also contribute to chin deviation. The importance of this factor will be investigated in the future. In our study, the direction of chin deviation was associated with the difference between left and right mandibular effective length. Therefore, asymmetry in the lower face was most closely associated with the amount and direction of chin deviation.

Our study showed that asymmetry in other facial areas existed in patients with chin deviation. Correction of chin deviation by mandibular jaw surgery or genioplasty alone could not remove the asymmetry in other areas that might be significant and of concern to patients. Our experience also revealed that pure mandibular setback surgery to correct the anteroposterior jaw relation and malocclusion on skeletal Class III patients associated with severe chin deviation might not achieve a complete correction of the deviated chin. The need for genioplasty to assist the transverse correction of the midline of the chin should be carefully evaluated before surgery. Therefore, thorough facial examination and explanation of the procedure to the patient are imperative during treatment planning to ensure patient satisfaction.

In conclusion, this study analyzed the facial skeletal characteristics of 25 patients with chins that deviated more than 2 mm using PA cephalograms. The following were found:
1. Seventeen subjects (68%) showed chin deviation to the left side and 8 subjects (32%) to the right. Sixty-eight percent of subjects presented with Angle Class III malocclusion.
2. Horizontal distance of all paired lateral points to the y-axis, mandibular body length and effective length showed a low grade of symmetry. Only vertical distances of paired ZF and zygonion points to the x-axis were asymmetric. However, there were no significant asymmetries of gonial angle, ramus height or vertical distances from other paired lateral points to the x-axis.
3. The amount of chin deviation was associated with the absolute differences of the left and right AGN to the y-axis and the ZF to the x-axis in multiple regression analysis.
4. The direction of chin deviation was significantly associated with the difference in bilateral mandibular effective length. For every 1 mm the left mandibular effective length was longer than that of the right side, the possibility of chin deviation to the right side was 2.2 fold that of the left.

Acknowledgments

This work was sponsored by grants VGH94-242C, CI95-16 and NSC94-B-2314.

References

4. Ferrario VF, Sforza C, Poggio CE, Tartaglia G. Distance from
5. Ferrario VF, Sforza C, Ciusa V, Dellavia C, Tartaglia GM. The
effect of sex and age on facial asymmetry in healthy subjects: a
6. Zaidel DW, Cohen JA. The face, beauty, and symmetry: per-
ceiving asymmetry in beautiful faces. Int J Neurosci 2005;
115:1165–73.
7. Liukkonen M, Sillanmaki L, Peltomaki T. Mandibular asym-
168–72.
8. Chen FM, Lin TY, Peng CH, Tsay CH, Huang TH, Kao CT. A
9. Severt TR, Proffit WR. The prevalence of facial asymmetry in
the dentofacial deformities population at the University of
10. Bishara S, Burkey PS, Kharouf JG. Dental and facial asymme-
11. Pirttiniemi P. Associations of mandibular and facial asymme-
12. Pirttiniemi P. Normal and increased functional asymmetries in
14. Forsberg CT, Burston CJ, Hanley KJ. Diagnosis and treatment
planning of skeletal asymmetry with the submental vertical
15. Profit WR, White RP. Surgical-orthodontic Treatment. St Louis:
16. Pirttiniemi P, Kantoma T. Relation of glenoid fossa morphol-
gy to mandibulofacial asymmetry, studied in dry human Lapp
17. Melnick AK. A cephalometric study of mandibular asymmetry in
a longitudinally followed sample of growing children. Am J
18. Kiliaridis S, Bresin A, Holm J, Strid KG. Effects of masticatory
muscle function on bone mass in the mandible of the growing
19. Kiliaridis S, Engstrom C, Lindskog-Stockland B, Katsaros C. Craniofa-
cial bone remodeling in growing rats fed a low-
calcium and vitamin-D-deficient diet and the influence of mas-
20. Raadsheer MC, Kiliaridis S, Van Eijden TM, Van Ginkel FC,
Prahl-Andersen B. Masseter muscle thickness in growing
individuals and its relation to facial morphology. Arch Oral Biol
1996;41:323–32.
21. Bruce RA, Hayward JR. Condylar hyperplasia and mandibular
22. Obwegeser HL, Makek MS. Hemimandibular hyperplasia: hemi-
23. Persson M. Mandibular asymmetry of hereditary origin. Am J
24. Stabrum AE, Larheim TA, Høyreland HM, Røsler M. Reduced
mandibular dimensions and asymmetry in juvenile rheumatoid
25. Speculand B. Unilateral condylar hypoplasia with ankylosis:
26. Lund K. Mandibular growth and remodeling process after
27. Pliot DA, Ellisdon PS. Facial asymmetries and mandibular dis-
29. Kambylaftas P, Kyranides S, Tallents RH. Mandibular asym-
metry in adult patients with unilateral degenerative joint dis-
30. Eisenberg RL, Dennis CA, May CR. Radiographic Positioning,
32. Haraguchi S, Takada K, Yasuda Y. Facial asymmetry in subjects
33. Lin TY, Huang CC, Huang TH, Kao CT. Postsroanterior
cephalometric assessment of different malocclusions in adults.
34. Chang HP. Components of class III malocclusion in Chinese.
35. Kao CT, Chen FM, Lin TY, Huang TH. The craniofacial mor-
phologic structure of the adult with Class III malocclusion. Int
36. Chou IC, Fong HJ, Kuang SH, Gi LY, Hwang FY, Lai YC,
Chang CS, et al. A retrospective analysis of the stability and
relapse of soft and hard tissue change after bilateral sagittal split
37. Padwa BL, Kaiser MO, Kaban LB. Occlusal cant in the frontal
plane as a reflection of facial asymmetry. J Oral Maxillofac Surg
38. Langberg BJ, Arai K, Miner RM. Transverse skeletal and dental