Research Article

Analysis of Three-Dimensional Morphological Differences in the Mandible between Skeletal Class I and Class II with CBCT Fixed-Point Measurement Method

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This study was aimed at determining the three-dimensional differences in the mandible morphology between skeletal class I and II patients, at exploring the pathogenic mechanisms and morphological characteristics of skeletal class II, and at providing clinical references. The subjects were assigned to two groups according to the size of ANB angle: skeletal class I (2° < ANB angle < 5°) and skeletal class II (5° < ANB angle < 8°). After cone-beam computed tomography (CBCT) scanning, 31 landmarks and 25 measurement items were determined by In Vivo Dental 5.1 software (Anatomage, CA) for statistical analysis. The results were as follows: Co-Go, Go-Me, and CdM-CdD in skeletal class II cases were smaller than those in skeletal class I, and GoR-Me-GoL, GoR-Me-CoL, and Ig-Men were larger than those in skeletal class I cases. In conclusion, there were significant differences in the three-dimensional morphology of the mandible between skeletal class I and class II patients. The vertical growth of the ramus, the horizontal growth of the mandibular body, and the condyle in skeletal class II patients were smaller than those in skeletal class I cases. In skeletal class II, the growth of the anterior part of the mandible in the vertical direction was larger than that in skeletal class I, and the shape of the mandible was more extended.

1. Introduction

Skeletal class II malocclusion is a common jaw deformity in the clinic, with a prevalence rate of approximately 20%. It is characterized by abnormal mandibular morphology and abnormal sagittal position between the maxilla and mandible [1]. The mandible is an important component of the craniofacial complex, in the lower one-third of the face. Genetic and environmental factors impact mandibular size and morphology easily, which play an important role in the esthetic appearance and function of the maxillofacial region. Uncoordinated facial contour caused by the mandible is one of the most common causes for patients seeking orthodontic treatment [2]. Therefore, orthodontists should pay close attention to the mandibular size, morphology, position, and rotation angle to select an appropriate treatment plan [3].

CBCT has the advantages of fast scanning, low effective radiation dose, simple procedural steps, etc. Its accuracy of the three-dimensional reconstruction is high, with a true one-to-one measure of craniofacial anatomy. It can be directly measured on three-dimensional reconstructed images, similar to the anatomical measurement [4–7]. The extensive application of CBCT in the clinic and the increasingly optimized third-party image processing software significantly improve the measurement of craniomaxillofacial structures, providing more accurate and comprehensive information [8].

The mandible is a three-dimensional structure with an irregular shape. Two-dimensional images cannot fully and accurately reflect the actual situation of three-dimensional structures. Thus, in clinical orthodontics, three-dimensional reconstruction and measurement analysis of the mandible
is of great significance [9]. Despite some achievements in the three-dimensional morphology of the mandible, the data are still relatively scarce. This study was aimed at determining the three-dimensional mandibular morphology in patients with skeletal class I and class II malocclusion, at exploring the differences between them, and at providing a reference for the pathogenesis, classification, and treatment of skeletal class II malocclusion.

2. Materials and Methods

2.1. Case Selection. The total sample (72 volunteers) was obtained at the Orthodontic Department, Affiliated Hospital of Qingdao University.

The inclusion criteria were as follows: (1) Han nationality aged 18-25 years, (2) facial symmetry, (3) complete dentition, and (4) clear and complete CBCT images.

The exclusion criteria were as follows: (1) history of oral and maxillofacial trauma, (2) history of orthodontic or orthognathic treatment, (3) severe soft and hard tissue lesions in the maxillofacial region, (4) systemic diseases, and (5) blurred, distorted, and overlapping CBCT images with effects, affecting the identification and measurement.

The subjects were divided into class I or class II skeletal patterns, according to the ANB angle.

- **Skeletal class I** ($2^{\circ} < \text{ANB angle} < 5^{\circ}$): 36 cases, including 18 males and 18 females.
- **Skeletal class II** ($5^{\circ} < \text{ANB angle} < 8^{\circ}$): 36 cases, including 18 males and 18 females.

2.2. Scanning and Reconstruction. The CBCT images of the patients were captured by a CBCT unit (Pax-Zenith3d, EWOO-VATECH, Korea). The subjects' facial midline was adjusted perpendicular to the floor, the head position was fixed, and the lips were occluded and closed naturally, breathing calmly without swallowing. The source data of volunteers were obtained and stored in a DICOM format: scanning range: wide field; scanning conditions: tube voltage 90 kV and tube current 4 mA. DICOM files were imported into the same orthodontic workstation computer installed with In Vivo Dental 5.1 software to reconstruct the image data.

2.3. Determination of Mark Points and Measurement Items. Ideal landmarks should be anatomic landmarks that are easy to locate and relatively stable, reflecting the morphological characteristics of the mandible. Through literature review and analysis, 31 commonly used three-dimensional measurement landmarks of the mandible were selected. It includes 5 coordinate system points, 6 single points, and 20 paired points (Table 1).

According to the relevant literatures, a total of 25 line distance and angle measurements were selected to describe the morphological characteristics of the mandible, of which 10 measurements were used to describe the characteristics of the mandibular ramus, and 8 measurements were used to describe the characteristics of condyle and coracoid process [10–12]. The line distance is measured in "mm" and the angle is measured in "°" (Table 2).

2.4. Three-Dimensional Items. A 3D analysis module of In Vivo Dental 5.1 software was used to fix 3D points. Turn on the "slice locator" function to display the position of the marked points in the cross section, sagittal plane, and coronal plane. Adjusting the position by moving three-dimensional landmarks on the three sections and combining with the three-dimensional model of the head, the accuracy and reliability of the three-dimensional fixed point can be improved. The 3D positioning maps of some landmark points are shown in Figure 1.

2.5. Three-Dimensional Measurement. 25 measurement items were set in the 3D analysis module of In Vivo Dental 5.1 software. After the 3D fixed point was completed, set line distance and angle measurement values were automatically obtained. Each patient was measured twice by the same person with an interval of one week, and the average value of the two measurements was taken as the 3D measurement result (Figures 2–4).

2.6. Statistical Analysis. SPSS (IBM, USA) was used for statistical analysis. The statistical differences between class I and class II, between class I men and class II men, and between class I women and class II women were compared. Shapiro-Wilk test was used to determine whether the data were in accordance with normal distribution, and independent sample t-test was used for the difference. $P < 0.05$ indicates a significant difference.

3. Result

3.1. Skeletal Class I and Class II. There were six items with statistical difference between skeletal class I and skeletal class II (Table 3). Co-Go, Go-Me, and CdM-CdD of skeletal class II were smaller than those of skeletal class I. Ig-Men, GoR-Me-GoL, and CoR-Me-CoL were larger than those of skeletal class I. There was no significant difference in other measurement items.

3.2. Skeletal Class I and Class II in Male. Go-Me and CdM-CdD of skeletal class II were smaller than those of skeletal class I. Ig-Men and GoR-Me-GoL were larger than those of skeletal class I (Table 4).

3.3. Skeletal Class I and Class II in Female. Go-Me, Co-Go, CdM-CdD, and CdA-CdP in skeletal class II were smaller than those in skeletal class I (Table 5).

4. Discussion

4.1. Advantages of Three-Dimensional Measurement in the Mandible. Three-dimensional measurement technology includes laser scanning technology, structured light scanning technology, X-ray technology, and spiral CT scanning technology, which is widely used in clinical and scientific researches [9, 13–16]. The early study of the mandible was mainly based on lateral cephalogram. Technological advances in CBCT appear to offer significant advantages in both quality and quantity of data representing true anatomy [17, 18]. We can analyze morphological structure and
position of the mandible in three-dimensional direction by using CBCT, so as to better refer to the scientific research and clinical work in the field of orthodontics.

Accurate fixed location of anatomical landmarks is the premise of obtaining reliable analysis results. The three-dimensional landmarks selected in this experiment are supported by previous literatures [19]. They are easy to determine, with rare variation, which can truly reflect the shape and structure of the mandible [10–12]. Point Co and other paired points are independent and related to each other. In the traditional two-dimensional measurement method, the images of these points are the superposition or the mean value of the two, which ignore part of the superposition or the mandible, causing loss of mandibular information. In this experiment, the paired points were marked separately to increase the transverse line distance of the mandible, such as GoR-GoL, MfR-MfL, and CdM-cDd, which reflected the horizontal characteristics of the mandible and obtained more comprehensive information to describe the characteristics of the mandible.

The three-dimensional measurement makes it possible to measure the items that cannot be measured on a two-

| Landmarks                  | Abbreviation | Definition                                                                 |
|---------------------------|--------------|-----------------------------------------------------------------------------|
| Coordinate system points  |              |                                                                             |
| Nasion                    | N            | The most anterior point of the nasal frontal suture                         |
| Right porion              | Po-R         | The uppermost point of right external auditory canal                         |
| Right orbitale            | Or-R         | The lowest point of the right infraorbital margin                           |
| Anterior nasal spine      | ANS          | The apex of the anterior nasal ridge                                        |
| Basion                    | Ba           | The midpoint of the anterior edge of foramen magnum                         |
| Sellar                    | S            | The central point of the pituitary fossa                                   |
| A                         | A            | The most concave point of the bone between the point of anterior nasal ridge and the point of superior alveolar margin |
| B                         | B            | The most concave point of the bone between the point of the inferior alveolar margin and the point of the anterior chin |
| Gnathion                  | Gn           | The midpoint between the anterior point of chin and the submental point     |
| Menton                    | Men          | The lowest point of the chin                                                |
| Ig                        | Ig           | The apex of alveoli between lower central incisors                          |
| Left gonion               | Go-L         | Posterior inferior point of left mandibular angle                           |
| Right gonion              | Go-R         | Posterior inferior point of right mandibular angle                          |
| Internal point of left condyle | Co-L      | The uppermost point of the left condyle                                     |
| Internal point of right condyle | Co-R    | The uppermost point of the right condyle                                    |
| External point of left condyle | CdML    | The innermost point of the left condyle                                     |
| External point of right condyle | CdMR   | The innermost point of the right condyle                                    |
| Anterior point of left condyle | CdAL   | The most lateral point of the left condyle                                  |
| Anterior point of right condyle | CdAR    | The most lateral point of the right condyle                                 |
| Posterior point of left condyle | CdPL  | The last point of the left condyle                                          |
| Posterior point of right condyle | GdPR   | The last point of the right condyle                                         |
| Apex of left coracoid process | Cc-L     | The uppermost point of the left coracoid process                            |
| Apex of right coracoid process | Cc-R     | The uppermost point of the right coracoid process                           |
| Left sigmoid notch        | Sg-L         | The lowest point of the left sigmoid notch                                  |
| Right sigmoid notch       | Sg-R         | The lowest point of the right sigmoid notch                                 |
| Left mandibular inflection | Ma-L        | The most concave and outermost point between left anterior edge of ramus and mandibular body turning point |
| Right mandibular inflection | Ma-R        | The most concave and outermost point between right anterior edge of ramus and mandibular body turning point |
| Left mental foramen       | Mf-L         | The lateral superior point of the left mental foramen on the anterior surface of the mandible |
| Right mental foramen      | Mf-R         | The lateral superior point of the right mental foramen on the anterior surface of the mandible |
The condyle undergoes cartilaginous growth. These findings suggest that mandibular condylar growth is insufficient, and mandibular body length is underdeveloped in skeletal class II patients.

In skeletal class II, GoR-Me-GoL and CoR-Me-CoL were larger than those in skeletal class I patients. The growth of the ramus height mainly depends on the new bone apposition in the mandibular condyle. The increase in mandibular body length is mainly due to the apposition of new bone on the lateral aspect of the mandible and the absorption of old bone on the medial aspect. The condyle undergoes cartilaginous growth. These findings suggest that mandibular condylar growth is insufficient, and mandibular body length is underdeveloped in skeletal class II patients.

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increasing bone deposition on the posterior part of the mandible, which decreases the curvature of the mandible.

Mandibular body height mainly depends on the growth of the alveolar process when the mandibular teeth erupt. The mandibular body height in skeletal class II patients is higher than that in skeletal class I patients, indicating that the mandibular anterior alveolar bone is overdeveloped, while the skeletal class II patients are prone to deep overbite. On the other hand, hypoplasia of mandibular body length leads to deep overjet. The anterior teeth do not contact, resulting in their supraspinatus and deep overbite.

Three-dimensional morphological differences of the mandible have their own special features in males and females. The mandibular body length and condyle width of skeletal class II male and female patients were smaller than those in skeletal class I male and female patients, respectively, consistent with the differences between the groups.

The mandibular ramus height and the condylar thickness in skeletal class II female patients were smaller than those in skeletal class I female patients, with no significant differences in these items in males. The growth of the mandibular ramus height ascending branch mainly depends on the apposition of the new bone in the mandibular condyle, which is the growth center of the mandible [28, 29]. The reason might be that the mandibular

Figure 1: The 3D positioning maps of (a) N, (b) S, (c) ANS, (d) Po-R, (e) Co-L, (f) Go-L, (g) Men, (h) Cc-R, and (i) CdDR.
hypoplasia in females is more significantly affected by genetic factors, and condylar growth deficiency is responsible for this in males.

The opening of the mandibular body relative to Me and the mandibular body height in skeletal class II male patients were greater than those in skeletal class I male patients, with no significant difference in these items in females. The growth of the mandibular body height mainly depends on the increase in the alveolar process height during the eruption of the mandibular teeth [30]. The reason might be that mandibular hypoplasia in skeletal class II males is more significantly affected by environmental factors, and the compensation of muscles and the alveolar process is the main cause.

There was no significant difference in the distance between paired points, such as the width of the mandibular body and the distance between the sigmoid notch. There was no significant difference in the anteroposterior, mesial, and distal inclination of the ramus and condyle, indicating that the mandible in skeletal class II patients did not affect these items. Bayome et al. scanned the CBCT scans of 38 young adults with normal occlusion and found that the mandible in males was larger than that in females, but the mandibular angle in females was larger [20]. There is a moderate to strong correlation between several vertical and horizontal variables; for example, there is a negative correlation between condylar anteroposterior inclination and mandibular angle and a negative correlation between

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**Figure 2:** Three-dimensional measurement result of (a) angle and (b) line distance (anterior view).

**Figure 3:** Three-dimensional measurement result of (a) angle and (b) line distance (45° lateral view).
the ramus length and mandibular angle. It provides us with further research direction. The three-dimensional measurement of the mandibular shape and position should be further explored, and the pathogenic mechanism and morphological characteristics of skeletal class II patients should be studied to better guide the clinical diagnosis, scheme formulation, and prognosis evaluation in orthodontic treatment, orthognathic surgery, and other fields.

### 5. Conclusion

(A) There were statistically significant differences between skeletal class I and class II patients in the three-dimensional morphology of the mandible. The mandibular ramus height, mandibular body length, and condylar width in skeletal class II patients were smaller than those in skeletal class I patients. The mandibular body height in skeletal class II patients was higher than that in skeletal class I patients. The mandibular shape was more extended.

(B) CBCT-assisted In Vivo Dental 5.1 software is a practical and effective method to study the three-dimensional morphology of the mandible. It can initially form a three-dimensional measurement method of the mandible, accurately describe the mandibular shape three-dimensionally, and guide clinical practice.

### Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

### Table 3: The difference between skeletal class I and skeletal class II (x ± s).

| Measurement landmark | Skeletal class I (male) | Skeletal class II (male) | P value |
|----------------------|------------------------|--------------------------|---------|
| Co-Go                | 61.080 ± 4.690         | 57.527 ± 5.857           | 0.012   |
| Ig-Men               | 29.655 ± 2.073         | 31.049 ± 29.40           | 0.039   |
| Go-Me                | 83.524 ± 4.242         | 80.312 ± 3.413           | 0.002   |
| CdM-CdD              | 19.045 ± 2.051         | 17.135 ± 2.528           | 0.002   |
| GoR-Me-GoL           | 67.779 ± 4.516         | 70.586 ± 4.368           | 0.017   |
| CoR-Me-CoL           | 50.694 ± 2.951         | 52.439 ± 2.661           | 0.019   |

### Table 4: The difference between skeletal class I and skeletal class II in male (x ± s).

| Measurement landmark | Skeletal class I (male) | Skeletal class II (male) | P value |
|----------------------|------------------------|--------------------------|---------|
| Co-Go                | 84.979 ± 4.339         | 81.526 ± 3.168           | 0.019   |
| Ig-Men               | 30.599 ± 1.588         | 33.033 ± 2.654           | 0.005   |
| CdM-CdD              | 20.086 ± 1.985         | 18.326 ± 2.346           | 0.035   |
| GoR-Me-GoL           | 68.972 ± 4.252         | 73.081 ± 3.518           | 0.007   |

### Table 5: The difference between skeletal class I and skeletal class II in female (x ± s).

| Measurement landmark | Skeletal class I (female) | Skeletal class II (female) | P value |
|----------------------|---------------------------|---------------------------|---------|
| Go-Me                | 82.069 ± 3.729            | 79.099 ± 3.308            | 0.029   |
| Co-Go                | 58.814 ± 2.599            | 53.324 ± 4.150            | 0.0001  |
| CdM-CdD              | 18.005 ± 1.567            | 15.943 ± 2.165            | 0.006   |
| CdA-CdP              | 10.567 ± 1.370            | 9.442 ± 1.401             | 0.034   |

Figure 4: Three-dimensional measurement result of (a) angle and (b) line distance (lateral view).
Conflicts of Interest

The authors declare no competing interests.

Authors’ Contributions

Qiang Dong, HaoYu Shi, and Qi Jia contributed equally to this work.

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