ABSTRACT

Aim: To obtain the distribution of different maxilla-mandibular characteristics in Chinese skeletal class II mixed dentition patients and to compare the differences of cephalometric variables among different maxilla-mandibular types.

Materials and methods: A cross-sectional study was conducted among 310 skeletal class II patients in mixed dentition. The patients were divided into 6 groups according to SNA and SNB angle of the cephalogram. A total of 38 cephalometric measurements were measured on their cephalograms. Differences among groups were tested by one-way analysis of variance.

Results: There were 34 (10.97%) patients in group I, 10 (3.23%) in group II, 4 (1.29%) in group III, 69 (22.26%) in group IV, 133 (42.90%) in group V, and 60 (19.35%) in group VI. In all, 14.19% of the patients exhibited maxillary protrusion (MxP), and 62.26% exhibited mandibular retrusion (MnR) with either normal or retruded maxilla. Groups II and III were excluded for statistical comparison due to a limited sample size. Statistical differences were found in 25 cephalometric measurements among the other 4 groups. Patients with MnR (groups V and VI) exhibited bigger sella angle, gonial angle, Frankfort mandibular plane angle, and smaller mandibular body length and ramus height than patients without MnR (p value < 0.05).

Conclusion: The most common etiology forming skeletal class II malocclusion in Chinese children was MnR, which was mainly caused by the small size and hyperdivergent growth direction of mandible.

Clinical significance: The study presents various cephalometric characteristics of Chinese skeletal class II malocclusions. The results indicated that for the early orthodontic treatment of Chinese class II children with mixed dentition, orthodontists might emphasize more importance to mandibular length augmentation and growth direction change in mandible.

Keywords: Cephalometrics, Craniomaxillofacial characteristics, Growth evaluation, Mixed dentition, Skeletal class II.

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INTRODUCTION

Skeletal class II malocclusion is a common type of discrepancy in children with mixed dentition. As a sagittal discrepancy problem, it has different discrepancy mechanisms based on the anteroposterior position of maxilla and mandible. There are six types: maxilla protrusion with normal mandible (MxP and MnN), maxilla protrusion with protruded mandible (MxP and MnP), maxilla protrusion with retruded mandible (MxP and MnR), normal maxilla and mandible (MxN and MnN), normal maxilla with retruded mandible (MxN and MnR), and retruded maxilla and mandible (MxR and MnR).1

Children with mixed dentition have relatively more growth potential.2 Better use of the growth potential could achieve more effective and stable outcomes. In Chinese children with mixed dentition seeking for orthopedic treatment, the most common malocclusion is the skeletal class II malocclusion.2 The correction of skeletal class II malocclusion includes both skeletal and dental effect. The ideal treatment effect that the orthodontists expect is skeletal effect such as mandibular length augmentation and condyle growth.4 Application of functional appliances (FAs), especially during the pubertal growth phase, could bring an extent of skeletal effect and dental effect,5,6 but unavoidably, and some side effects. The side effects of FAs include increase of occlusal plane and gonial angle (Ar-Go-Me), proclination of lower incisors, and retroclination of upper incisors.7,8 There are about 10 different FAs and their modified devices,9 and the treatment effects and side effects vary with different appliances. Different types of patients should be treated with appropriate approaches in order to get more skeletal effects and fewer side effects. Accurate analysis of facial types and discrepancy etiology is very important for the treatment plan.

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For the analysis of facial types and discrepancy mechanisms, cephalogram is the mainly used approach.\textsuperscript{10} The proportion varies in different racial and ethnic groups. Cephalometric studies showed 27% of dental class II patients had mandibular retrusion, and 57.3% of the patients had maxillary protrusion (MxP).\textsuperscript{11} However, Pancherz reported that ~48 to 49% of Caucasian skeletal class II children at the age of 8 to 10 years had mandible retrusion (MnR).\textsuperscript{12} The proportion varies in different racial and ethnic groups. The Mongoloid population, such as Chinese, Korean, Japanese, are apt to develop backward rotated mandible.\textsuperscript{13,14} In all, 12.9% of Chinese adult skeletal class II patients exhibited MxP and 60.8% exhibited MnR.\textsuperscript{15} For Chinese skeletal class II patients, with relatively more common MnR and smaller mandible, the treatment priority should be different. Therefore, for Chinese skeletal class II children, the application of FAs might be more important. However, the distribution of different types in Chinese skeletal class II patients with mixed dentition have not been explored. Analysis of the proportion and relevant etiology will help to understand the formation of skeletal class II malocclusion and determine the focus of follow-up research.

Thus, the aims of this study were to analyze the distribution of different maxilla-mandibular characteristics in Chinese skeletal class II mixed dentition patients and to compare the differences of cephalometric variables among different maxilla-mandibular types.

**Materials and Methods**

**Subjects**

This retrospective study was carried out at department of orthodontics, West China Hospital of Stomatology. The study protocol was approved by the Institutional Review Board of our Hospital (Approval no.WCHSIRB-D-2019-203). Both the patients seeking for treatment and their parents were informed about the possibility that the patients' records might be used for teaching and research purposes, and informed consent was obtained. A total of 310 patients were included in this study.

In this study, patients' medical records, panoramic radiograph, and cephalograms were selected from the database of our hospital and anonymized for analysis. The norms of ANB, SNA, and SNB angle were derived from the database of our hospital.\textsuperscript{16}

A total of 872 patients were screened. The inclusion criteria were as follows: (1) Chinese children between the age of 6 and 12 with dentition containing primary and permanent teeth; (2) patients registered in West China Hospital of Stomatology from May 2018 to August 2019; (3) the ANB angle of pretreatment cephalogram was more than 5°; (4) panoramic radiograph showed the permanent dentition was normally developed, without missing teeth or supernumerary teeth, and the tooth germs were taken into account as well; (5) intraoral examination showed no signs of abnormal tooth morphology such as peg-shaped teeth and fused teeth; and (6) pretreatment records with high-quality cephalograms.

Patients who manifested craniofacial syndromes, clefts, trauma, deformity secondary to systematic disease, and had orthodontic or orthognathic treatment before were excluded. After screening, 310 patients were included; subsequently cephalometric analysis and statistical analysis were performed.

**Cephalometry**

All the cephalograms were taken at the Department of Radiology in our Hospital according to standardized cephalometric radiographic procedures with natural head position and with teeth in centric occlusion.\textsuperscript{17}

The lateral cephalograms were obtained during the first visit, after which they were digitalized and analyzed (Uceph, version 780, Chengdu, China) by independent observers.

The patients were divided into six groups according to SNA and SNB angle of the cephalogram:\textsuperscript{16}

- **Group I** (n = 34): MxP and MnN, SNA > 85°, SNB ≥ 76°;
- **Group II** (n = 10): MxP and MnP, SNA > 85°, SNB > 82°;
- **Group III** (n = 4): MxP and MnR, SNA > 85°, SNB < 76°;
- **Group IV** (n = 69): MxN and MnN, SNA > 76°, SNB ≥ 76°;
- **Group V** (n = 133): MxN and MnR, SNA ≥ 76°, SNB < 79°, SNB < 76°; and
- **Group VI** (n = 60): MxR and MnR, SNA > 79°, SNB < 76°.

The cephalometric reference plane was the Frankfort horizontal (FH) plane. The definitions of landmarks and measurements are presented in Table 1 and Figure 1. There were 35 measurements, classified into five categories (Table 2):

**Table 1: Cephalometric landmarks and measurements definitions**

| Landmark | Definition |
|----------|------------|
| Orbitale (Or) | The lowest point on the average of the right and left borders of the bony orbit |
| Porion (P) | The midpoint of the line connecting the most superior point of the radiopacity generated by each of the two ear rods |
| Sella (S) | The center of sella turcica |
| Nasion (N) | The most anterior point of the frontonasal suture |
| Articulare (Ar) | Intersection of the lateral radiographic image of the posterior border of the ramus with the base of the occipital bone |
| Go (Gonion) | Midpoint of the angle of the mandible, found by bisecting the angle formed by the mandibular plane and a plane through articulare, posterior and along the portion of the mandibular ramus inferior to it |
| Anterior nasal spine (ANS) | Sharp median process formed by the forward prolongation of the two maxillae at the lower margin of the anterior aperture of the nose |
| Posterior nasal spine (PNS) | The most posterior point at the sagittal plane on the bony hard palate |
| Pogonion (Pog) | The most anterior point on the chin |
| Menton (Me) | The most inferior point on the mandibular symphysis in the midline |
| Gnathion (Gn) | The lowest, most anterior midline point on the symphysis of the mandible |
| Upper first molar (UMT) | Maxillary first molar mesial cusp |
| Upper incisor incisal, Edge (UE) | The incisal tip of the maxillary central incisor |
| Lower first molar (LMT) | Mandibular first molar mesial cusp |
| Lower incisor incisal, Edge (LE) | The incisal tip of the mandibular central incisor |
| Soft tissue nasion (N') | Intersection of the anterior cranial base plane and the forehead soft tissue border |
| Soft tissue pogonion (Pog') | The most anterior point on the chin in the midsagittal plane |
Distribution of Various Maxilla-Mandibular Positions in Skeletal Class II Malocclusions

Cranial measurements: sella angle (N-S-Ar, °), articulation angle (S-Ar-Go, °), S-N (mm), and S-Ar (mm).

Maxillary, mandibular, and maxillomandibular skeletal measurements: gonial angle (°), upper gonial angle (°), lower gonial angle (°), PP-FH (°), PP-MP (°), FH-NPo (Facial Angle) (°), mandibular body length (mm), ramus height (mm), A-N Perp distance (mm), Pog-N Perp distance (mm), and S-N/Go-Me (%).

Vertical relationship measurements: SN-MP (°), FMA (°), anterior facial height (mm), upper anterior facial height (N-ANS, mm), lower anterior facial height (ANS-Me, mm), posterior facial height (S-Go, mm), and facial height index (%).

Dental measurements: IMPA (°), FMIA (°), U1-SN (°), U1-L1 (interincisal angle, °) SN-OP (°), MP-OP (°), U6-PP (mm), and L6-PP (mm).

Soft tissue measurements: nasolabial angle (°), soft tissue facial angle (FH-NPg°), facial convexity angle (N’S-Pg°), UL-EP (mm), and LL-EP (mm).

Table 2: Comparison of cephalometric measurements of groups I, IV, V, and group VI (x ± s)

| Measurements                                      | G1 (n = 34) | GIV (n = 69) | GV (n = 133) | GVI (n = 60) | p   |
|--------------------------------------------------|-------------|--------------|--------------|--------------|-----|
| Cranial measurements                              |             |              |              |              |     |
| N-S-Ar (°)                                        | 119.197 ± 4.8716 | 121.620 ± 4.3181 | 125.088 ± 3.8672 | 128.417 ± 4.3790 | 0.000*** |
| S-Ar-Go (°)                                       | 152.547 ± 5.3424 | 150.874 ± 14.7090 | 150.358 ± 5.2182 | 148.902 ± 5.6986 | 0.240 |
| S-N (mm)                                          | 59.162 ± 3.7201 | 60.174 ± 4.5391 | 60.980 ± 4.8464 | 59.948 ± 4.3521 | 0.147 |
| S-Ar (mm)                                         | 30.788 ± 2.5506 | 31.235 ± 3.3530 | 31.089 ± 3.7132 | 29.498 ± 3.3808 | 0.016* |
| Maxillary, mandibular and maxillomandibular skeletal measurements |             |              |              |              |     |
| Gonial angle (°)                                  | 121.626 ± 6.2711 | 120.355 ± 5.8506 | 122.258 ± 6.0081 | 124.828 ± 7.0089 | 0.001** |
| Upper gonial angle (°)                            | 46.974 ± 3.3377 | 48.103 ± 15.2115 | 46.858 ± 3.3924 | 46.857 ± 3.5293 | 0.735 |
| Lower gonial angle (°)                            | 74.641 ± 4.8512 | 74.230 ± 4.3721 | 75.401 ± 4.4315 | 77.973 ± 5.8076 | 0.000*** |
| PP-FH (°)                                         | 0.335 ± 3.3737 | 0.061 ± 3.2640 | 0.310 ± 3.5715 | −0.963 ± 3.1914 | 0.102 |
| PP-MP (°)                                         | 26.432 ± 5.0115 | 27.001 ± 5.2106 | 28.411 ± 5.0399 | 31.828 ± 5.9304 | 0.000*** |
| FH-NPo (Facial Angle) (°)                         | 85.918 ± 3.3186 | 84.400 ± 2.2479 | 82.903 ± 2.8125 | 82.088 ± 2.3452 | 0.000*** |
| Mandibular body length (mm)                       | 60.959 ± 4.4724 | 62.054 ± 5.4937 | 60.549 ± 5.1136 | 58.233 ± 5.2490 | 0.001** |
| Ramus height (mm)                                 | 39.518 ± 3.1176 | 39.033 ± 5.8186 | 38.692 ± 3.9566 | 37.330 ± 3.8783 | 0.065 |
| A-N Perp distance (maxillary skeletal) (mm)       | 3.124 ± 3.0054 | 0.483 ± 2.0335 | −0.049 ± 2.6478 | −1.833 ± 2.3368 | 0.000*** |
| Pog-N Perp distance (mand. skeletal) (mm)         | −6.850 ± 5.5424 | −9.546 ± 3.9840 | −12.374 ± 5.0959 | −13.695 ± 4.2233 | 0.000*** |
| S-N/Go-Me (%)                                     | 96.082 ± 8.1939 | 96.910 ± 7.5442 | 99.765 ± 6.0968 | 102.723 ± 7.7084 | 0.000*** |
| Vertical relationship measurements                |             |              |              |              |     |
| SN-MP (°)                                         | 33.335 ± 5.0289 | 34.404 ± 4.4918 | 37.687 ± 4.4394 | 42.063 ± 5.7939 | 0.000*** |
| FMA (°)                                           | 26.735 ± 5.9613 | 27.233 ± 4.4354 | 28.689 ± 4.8483 | 30.893 ± 5.4483 | 0.000*** |
| Anterior facial height (mm)                       | 102.541 ± 4.8120 | 104.632 ± 8.2218 | 106.538 ± 8.5533 | 106.607 ± 8.0810 | 0.036* |
| Upper anterior facial height, N-ANS (mm)          | 46.356 ± 2.6656 | 47.567 ± 3.4740 | 48.765 ± 4.5107 | 48.218 ± 3.4777 | 0.008** |
| Lower anterior facial height, ANS-Me (mm)         | 55.203 ± 3.4811 | 55.807 ± 5.5889 | 56.037 ± 4.9425 | 56.392 ± 5.6307 | 0.737 |
| Posterior facial height (S-Go) (mm)               | 68.250 ± 3.8592 | 68.041 ± 7.7363 | 67.414 ± 6.1875 | 64.328 ± 5.7124 | 0.003** |
| Facial height Index (%)                           | 66.629 ± 3.8770 | 65.083 ± 5.9671 | 63.304 ± 3.4535 | 60.383 ± 3.4987 | 0.000*** |
| Dental measurements                               |             |              |              |              |     |
| IMPA (°)                                          | 97.868 ± 7.7346 | 97.570 ± 5.1673 | 99.262 ± 6.2497 | 95.285 ± 7.4341 | 0.009** |
| FMIA (°)                                          | 55.385 ± 7.2962 | 55.203 ± 5.8499 | 52.048 ± 5.9452 | 53.813 ± 6.1375 | 0.001** |
| U1-SN (°)                                         | 108.209 ± 9.9821 | 109.213 ± 8.0640 | 104.566 ± 8.3296 | 102.717 ± 10.5305 | 0.000*** |
| U1-L1 (interincisal angle) (°)                    | 120.585 ± 14.0433 | 118.812 ± 9.1669 | 118.478 ± 10.8300 | 119.937 ± 13.7186 | 0.727 |
| SN-OP (°)                                         | 18.800 ± 3.9699 | 19.726 ± 3.9418 | 22.013 ± 3.6525 | 24.667 ± 3.6695 | 0.000*** |
| MP-OP (°)                                         | 14.574 ± 4.1280 | 14.681 ± 4.2908 | 15.678 ± 4.2563 | 17.397 ± 5.5670 | 0.003** |
| U6-PP (mm)                                        | 16.506 ± 1.8918 | 16.162 ± 2.4600 | 16.208 ± 2.3649 | 16.197 ± 2.5863 | 0.912 |

Contd…
Distribution of Various Maxilla-Mandibular Positions in Skeletal Class II Malocclusions

The values for angular, linear, and proportion cephalometric measurements in each group were evaluated and compared, which are mentioned below.

Statistical Analysis
The interobserver and intra-observer reliability of cephalometry were tested. For interobserver reliability, 20 randomly selected cephalograms were measured by two observers, and the intraclass correlation coefficient (ICC) was calculated. For intra-observer reliability, 20 randomly selected cephalograms were measured by each examiner for the first time. After a washout period of about 1 month, the same cephalograms were repeatedly measured by the observer, and ICC was also calculated. The examiners were not qualified to measure cephalograms unless ICC was greater than 0.8.

Statistical analysis was performed with SPSS software (version 24.0, SPSS Inc, Chicago, IL, USA). The differences in the cephalometric measurements among the groups were evaluated through one-way analysis of variance (one-way ANOVA) when equal variances were assumed (p value > 0.05), and the Duncan multiple comparisons were performed done at a significance level of p value = 0.05 if the difference was statistically significant in one-way ANOVA (p value < 0.05).

Results
Demographic Characteristics
The 310 patients (175 females and 135 males) included in this study had a mean age of 9.24 ± 1.09 years. The most common sagittal skeletal type was group V (MxN and MnR, 42.90%), followed by group IV (MxN and MnN, 22.26%), and group III (MxN and MnR) was the least (1.29%) (Table 3). The greatest ANB value was observed in group III (Fig. 2). As there were only 4 patients in group III and X patients in group II (MxP and MnP), these two groups were not included in the inferential statistics.

Cranial Measurements
Differences in sella angle and posterior cranial base length were statistically significant, whereas articular angle and anterior cranial base length showed no statistical differences among the 4 groups (Table 2). Group VI exhibited the greatest sella angle and the shortest posterior cranial base length, while group I exhibited the least sella angle (Table 4).

Maxillary, Mandibular, and Maxillomandibular Skeletal Measurements
Differences in gonial angle, lower gonial angle, PP-MP, FH-NPo (facial angle), mandibular body length, A-N Perp Distance, Pog-N Perp Distance, and S-N/Go-Me were statistically significant, whereas upper gonial angle, PP-FH, and ramus height showed no statistical differences among the 4 groups (Table 2). Group VI exhibited the greatest gonial angle, lower gonial angle, PP-MP, S-N/Go-Me, and the least mandibular body length, A-N Perp Distance. Group I exhibited the greatest facial angle, A-N Perp Distance, and Pog-N Perp Distance.

Vertical Relationship Measurements
Differences in SN-MP, FMA, anterior facial height, upper anterior facial height(N-ANS), posterior facial height(S-Go), and Facial Height

Table 3: Demographic characteristics of different skeletal types

| Measurements          | GI (n = 34) | GIV (n = 69) | GV (n = 133) | GVI (n = 60) | p    |
|----------------------|------------|-------------|-------------|-------------|------|
| L6-MP (mm)           | 27.553 ± 1.9274 | 27.932 ± 2.5256 | 28.056 ± 2.6646 | 27.470 ± 2.2129 | 0.408 |
| Soft tissue measurements                                      |
| Nasolabial A (°)     | 105.768 ± 10.3170 | 101.013 ± 12.6922 | 104.005 ± 10.3897 | 102.408 ± 12.1932 | 0.155 |
| FH-N’S’ (S.T. facial angle) (°) | 85.918 ± 3.3186 | 84.400 ± 2.2479 | 82.903 ± 2.8125 | 82.088 ± 2.3452 | 0.000*** |
| N'-Sn-Pg (facial convexity angle) (°) | 156.806 ± 5.2693 | 160.967 ± 4.8152 | 158.986 ± 4.2796 | 160.233 ± 4.3701 | 0.000*** |
| UL-EP (mm)           | 4.729 ± 2.3498 | 3.878 ± 2.0479 | 4.568 ± 2.0878 | 3.698 ± 1.9396 | 0.011*  |
| LL-EP (mm)           | 4.871 ± 2.6719 | 3.716 ± 2.8761 | 4.867 ± 2.6372 | 4.440 ± 2.3261 | 0.027** |

*p < 0.05; **p < 0.01; ***p < 0.001

Fig. 2: Distribution of ANB values in types of skeletal class II malocclusions

(Table 2). Group VI exhibited the greatest sella angle and the shortest posterior cranial base length, while group I exhibited the least sella angle (Table 4).
Table 4: Duncan multiple range test for group comparison

| Measurements                          | Homogeneous subsets with statistically significant difference (p < 0.05)* |
|---------------------------------------|---------------------------------------------------------------------|
| N-S-Ar (°)                            | 1 < 4 < 5 < 6                                                       |
| S-Ar (mm)                             | 6 < (1, 5, 4)                                                      |
| Gonial angle (°)                      | (4, 1, 5) < 6                                                      |
| Lower gonial angle (°)                | (4, 1, 5) < 6                                                      |
| PP-MP (°)                             | (1, 4, 5) < 6                                                      |
| FH-NPo (Facial angle) (°)             | (6, 5) < 4 < 1                                                     |
| Mandibular body length (mm)           | 6 < (5, 1, 4)                                                      |
| A-N Perp distance (Maxillary skeletal) (mm) | 6 < (5, 4) < 1                                           |
| Pog-N Perp distance (Mand. skeletal) (mm) | (6, 5) < 4 < 1                                               |
| S-N/Go-Me (%)                        | (1, 4) < 5 < 6                                                      |
| SN-MP (°)                             | 1 < 4 < 5 < 6                                                      |
| FMA (°)                               | (1, 4) < (4, 5) < 6                                               |
| Anterior facial height (mm)           | (1, 4) < (4, 5, 6)                                                |
| Upper anterior facial height, N-ANS  (mm) | (1, 4) < (4, 6, 5)                                            |
| Posterior facial height (S-Go) (mm)   | 6 < (5, 4, 1)                                                     |
| Facial height index (%)               | 6 < 5 < 4 < 1                                                      |
| IMPA (°)                              | (6, 4, 1) < (4, 1, 5)                                             |
| FMIA (°)                              | (5, 6) < (6, 4, 1)                                                |
| U1-SN (°)                             | (6, 5) < (1, 4)                                                   |
| SN-OP (°)                             | (1, 4) < 5 < 6                                                    |
| MP-OP (°)                             | (1, 4, 5) < 6                                                    |
| FH-N’Pg (S.T. facial angle) (°)       | (6, 5) < 4 < 1                                                    |
| N’-Sn-Pg (Facial convexity angle) (°) | 1 < (5, 6) < (6, 4)                                               |
| UL-EP (mm)                            | (6, 4) < (4, 5) < (5, 1)                                          |
| LL-EP (mm)                            | (4, 6) < (6, 5, 1)                                                |

Index were statistically significant, whereas lower anterior facial height (ANS-Me) showed no statistical differences among the 4 groups (Table 2). Facial Height Index had the most effective ability to discriminate the differences among the 4 groups compared to other variables related to vertical relationship (Table 4). Group I exhibited the greatest posterior facial height, facial height index, and the least SN-MP, FMA, anterior facial height, and upper anterior facial height (Table 4).

Dental Measurements
Differences in IMPA, FMIA, U1-SN, SN-OP, and MP-OP were statistically significant, whereas Interincisal Angle, U6-PP, and L6-PP showed no statistical differences among the 4 groups (Table 2). Group VI exhibited the greatest SN-OP, MP-OP, and smaller IMPA than group V. Group V showed smaller FMIA and U1-SN than groups I and IV (Table 4).

Soft Tissue Measurements
Differences in FH-N’Pg (S.T. Facial Angle), N’-Sn-Pg (Facial convexity angle), UL-EP, and LL-EP were statistically significant, whereas nasolabial showed no statistical differences among the 4 groups (Table 2). Group I exhibited the greatest S.T. facial angle and the least facial convexity angle. Group V showed smaller FMIA and U1-SN than groups I and IV (Table 4). Group VI showed smaller
shortest posterior cranial base. Louis23 revealed that patients with longer posterior cranial bases had more retruded mandibles. As the difference in sella angle was more remarkable, we could infer that the shorter posterior cranial base in group VI was to compensate for the bigger sella angle. Besides, the size of mandible in group VI was the smallest, and in vertical measurements, group VI had the biggest SN-MP and FH-MP. Thus, if orthopedic treatment could alter the growth direction and amount of mandible, guiding it to grow counterclockwise would be critical.24 For severe retruded and small mandible, it might be better to wait for orthognathic surgery and not to intervene early. For the treatment strategy of mild to moderate MxR and MnR, restricting the maxillary might need to be avoided, and in order to get a normal craniofacial relationship, promoting the growth of maxillary and creating enough space for mandible growth and counterclockwise rotation could be considered.

A remarkable advantage of this study is the large sample size. Compared to historic studies, more comprehensive cephalometric measurements were used to describe the features of different facial types from different aspects. We found that the main factor causing skeletal class II malocclusion in Chinese children with mixed dentition was MnR, which exhibited a relatively small size and clockwise-rotation tendency of mandible. Thus, the importance of FAs for Chinese class II children should be reconsidered thoroughly. There might be more need for length augmentation and growth direction change of mandible in Chinese children. Several studies reported the favorable effects of FAs in Mongolid children and young adults.25–27 With more clinical trials in the future confirming the effects of FAs in Mongolid population, especially Chinese, the application of FAs could be encouraged.

One major limitation of this study was that the relative jaw relationship was determined by ANB angle. The ANB angle is mostly used by clinicians, and it is directly related to the cranial base, which helps us to illustrate mechanisms. However, based on some studies, ANB angle did have some fallacies,28 as it might be influenced by sagittal position of point N, length of anterior cranial base, maxillary rotation, and vertical distance between point A and B as well as point N and B. In our study, the length of anterior cranial base showed no significant differences in each group. And B as well as point N and B. In our study, the length of anterior cranial base showed no significant differences in each group. And we evaluated A-N Perp Distance, Pog-N Perp Distance according to McNamara analysis,29 which showed a similar trend with SNA and SNB. The error caused by ANB angle was relatively small.

**Conclusion**

This cross-sectional study showed that the most common etiology forming skeletal class II malocclusion in Chinese children was mandibular retrusion, which was mainly caused by the small size and hyperdivergent growth direction of the mandible. For the early orthodontic treatment of Chinese class II children with mixed dentition, orthodontists should emphasize mandibular length augmentation and growth direction change of mandible.

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