Original Article

# Mandibular Position Changes Following Three Treatment Modalities in Class II Division 1 Growing Patients

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## Abstract

This retrospective study aimed to investigate the effects of different orthodontic treatment modalities on mandibular positions in Class II division 1 growing patients. The 96 patients, (48 boys, 48 girls) aged 11.7±1.6 years were equally divided into three groups: the cervical headgear group, the extraction of four first premolars, and the Class II traction. Significant changes of the mandibular positions and related structures were evaluated from pre- and post-treatment lateral cephalograms by angular and linear measurements as well as the x-y coordinate system. The paired t-test or the Wilcoxon signed rank test was applied to investigate significant changes within groups, and differences between groups were evaluated by ANOVA or the Kruskal Wallis H test. Factors influencing the significant changes of mandibular positions were evaluated by stepwise multiple regression analysis at a $P<0.05$ significance level. The result indicated significant changes of mandibular position after treatment. Nonextraction treatment with cervical headgear followed by fixed edgewise appliance produced the most significantly forward and downward movements of the mandible with forward rotation. Mandibular rotation was the most important factor affecting the anterior position of the chin, followed by the horizontal growth of the condyle. Meanwhile, the downward movement of the maxilla at the A point and the vertical growth of the condyle were significantly affected by the vertical position of the chin. In conclusion, alterations of mandibular positions after treatment of Class II division 1 malocclusion could be expected depending on growth potential of the patient. Significant differences of mandibular positions between treatment groups could be detected when evaluated by the x-y coordinate system. Forward and downward displacements of the mandible with forward rotation were the most remarkable in the headgear group followed by the extraction and Class II traction groups, respectively.

**Keywords:** Class II division 1 malocclusion, Cervical headgear, Extraction, Class II traction, Mandibular position

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## Introduction

Remarkable characteristics of Class II division 1 malocclusion comprising of maxillary incisal protrusion with excessive overbite and overjet are the primary motivation of patients seeking for treatment at various ages. The previous study indicated that most patients present not only dental problem but also skeletal Class II discrepancy involving the retrusive mandible.[1] The difference between skeletal Class II malocclusion and skeletal Class I is mainly due to the retrusive mandible (less SNB angle) than the protrusive maxilla (more SNA angle),[2] and this malocclusion is not self-correction.[3] It is the responsibility of an orthodontist to select the appropriate treatment for an individual patient.

There are several treatment modalities to correct Class II division 1 malocclusion. However, the treatment effect remains controversial especially in the mandibular position. A headgear appliance is prescribed upon the assumption that it can produce orthopedic effect on the maxilla by restraining the forward growth and enhancing the mandible to express the maximum growth potential. One study reported that the cervical headgear inhibited horizontal displacement of the mandible during treatment,[4] the other found anterior rotation of the mandible with the anterior position.[5] Moreover, it could distalize the upper molars providing available space for correction of crowding.[6] Extraction of premolar teeth is another method to correct dental protrusion in non-growing patients.[7] The previous studies showed that the mandibular position of these patients was not significantly changed after treatment.[8,9] The chin point showed backward movement in both extraction and non-extraction patients.10 Class II traction is also suggested in the treatment of Class II malocclusion, especially in patients who have maxillary incisal protrusion and mandibular incisal retroclination.[11] Its effect on the backward rotation of the mandible with posterior displacement of the chin was reported.[12]

The chin is an essential area in facial appearance and also one of the patient's concerns for orthodontic treatment.[13] However, as shown from the facial growth study, there was no bone deposition on the labial surface of the chin.[14] Buschang and Jacob[15] stated that the rotation of the mandible was the most important factor determining the antero-posterior position of the chin.

Moreover, the previous study indicated a significant relationship between mandibular position and the pharyngeal airway space, Class II patients with retrognathic mandible presented the narrowest pharyngeal space.[16,17] Therefore, recognizing the effect of each treatment modality on the position of Class II patients is beneficial not only for facial esthetics but also for respiratory function. The study was undertaken upon the hypothesis that treatment of Class II growing patients with various modalities could change the mandibular position.

The objectives of the study were to investigate the effects of various orthodontic treatments on the mandibular position in Class II division 1 growing patients and to compare significant differences among these treatment effects.

## Materials and methods

The study was undertaken after the approval of the Human Research Ethics Committee of the Faculty of Dentistry, Chulalongkorn University (HREC-DCU 2019-037). The sample size of 93 patients was estimated from G power program (version 3.1.9.3) to reach 80% statistical power by using a one way analysis of variance, with a significance level of 0.05, based on horizontal change of the pogonion point of the previous study.[18] The analyzed sample size in each group was 31 patients. Therefore, the sample of this study included 32 growing patients for three groups (48 boys, 48 girls) aged 11.7±1.6 years.

**The inclusion criteria were**

- Skeletal Class II, division 1 malocclusion analyzed by cephalometric analysis with an overjet larger than 5 mm, normal or excessive overbite
- Absence of congenital syndromes or defects, obvious facial asymmetry, extreme vertical disproportion or congenitally missing teeth
- No history of trauma that could alter facial growth and development
- A complete orthodontic record indicating patient history, age, sex, type of treatment, lateral cephalograms

taken before treatment (T1) and after treatment (T2) from the same radiographic machine. (Kodak 8000c system)

- At the end of treatment, all patients presented Class I molar and canine relationships with an overjet of 2-3 mm and an overbite that did not exceed one-third of the lower incisor crown height.[11]

All participants were purposively assigned into three treatment groups according to severity of malocclusion and development of dentition. The treatment was prescribed by one orthodontist (SV).

**Treatment protocols**

**Group 1:** Nonextraction treatment with cervical headgear followed by fixed appliances edgewise technique. The sample comprised 32 patients (16 boys, 16 girls) with a mean age 10.6±1.7, 10.9±1.6 years. Each patient was in the mixed dentition with unerupted permanent maxillary second molars, well-aligned lower teeth, or mild crowding that could be corrected during the leveling phase. Cephalometric analysis indicated skeletal Class II normal or decreased vertical skeletal relationship with severe upper incisor protrusion and convex profile. Clinical examination indicated that the convex profile was improved when the mandible was positioned forward. Patients with bimaxillary protrusion when the mandible was moved were excluded. The facial development evaluated from the hand wrist film had not passed the peak of pubertal growth.[19] The patients were recommended to wear a cervical headgear that delivered 500 grams per side via the permanent maxillary first molars for 12 - 14 hours per day for distalization of the maxillary first molars, so that Class I molar relation and adequate space for correction of the upper incisor protrusion could be achieved without extraction. The fixed appliance edgewise technique was prescribed in the second stage when Class I molar was achieved to obtain acceptable overbite, overjet, Class I molar, and canine relationships.

**Group 2:** Extraction of four first premolars: the sample comprised 32 patients (16 boys, 16 girls), mean aged 12.2±1.1, 11.3±1.2 years. Each patient was in the early permanent dentition stage with complete eruption of the second maxillary molars. The cephalometric analysis indicated severe protrusion of the incisors and convex facial profile.

**Group 3:** Class II traction group. The sample comprised 32 patients (16 boys, 16 girls), mean aged 12.8±1.7, 12.2±1.3 years. All were treated as a nonextraction case with fixed appliance edgewise technique, and Class II traction. Each patient was in the permanent dentition stage with fully erupted maxillary second molars, notable upper arch constriction especially the intercanine width that inhibited forward movement of the mandible, minor to moderate crowding that could be corrected simultaneously with arch expansion. The clinical examination indicated improvement of the facial profile when the mandible was positioned forward to obtain Class I molar and canine relationships. The fixed appliance edgewise technique was used for upper arch expansion and a class II traction force of 4.5 – 6.5 ounces (128 – 184 grams) per side was applied for full-time traction after obtaining arch compatibility.

**Measurements**

Both before (T1) and after (T2) films were traced by the first author (WS) on acetate papers and reference points *representing hard tissue structures were located (Fig. 1).*

Dental and skeletal changes were scrutinized by angular and linear measurements (Fig. 1) and the x-y coordinate system (Fig. 2).

The x-y coordinate system for cranial base superimposition comprised line 1 (SN of T1 - 7 degrees = X axis) and line 2 (perpendicular line to line 1 at S point = Y axis). The line 1 and line 2 of the T1 film were transferred to the T2 film by superimposition on the stable structures of the anterior cranial base[20] of the T1 film to evaluate the overall horizontal and vertical changes of the jaw positions

Changes of the dental, condyle and rotation of the jaw were evaluated by structural superimposition of the stable structures of the related jaw.[20] The occlusal plane (line connecting the overlap of the first permanent molars and incisors) the of the T1 radiograph served as the X-axis and the perpendicular line at the mesiobuccal cusp of the first molar served as the Y-axis (Fig. 3)

When the T2 film was superimposed on the stable structures of the T1 film. Jaw rotation was determined as the angular rotation of the SN- 7° line. The forward and backward rotations were assigned as the positive and negative values, respectively.

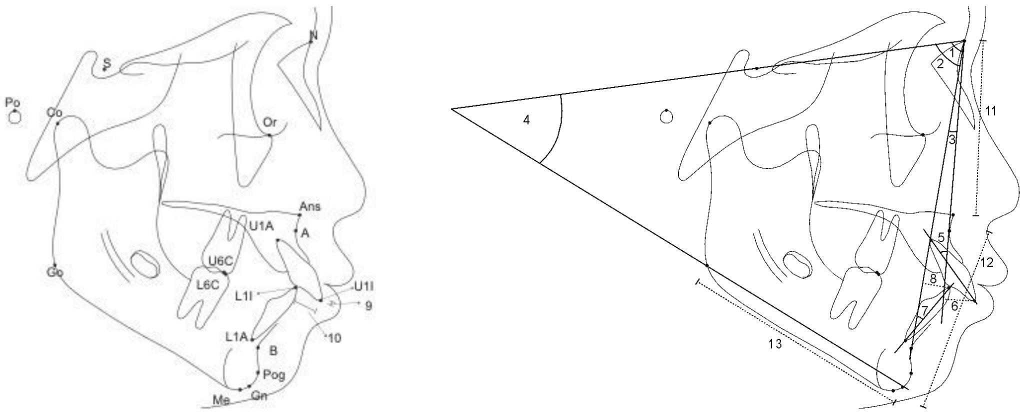


***Figure 1*** *Cephalometric landmarks and angular and linear measurements. 1 SNA angle, SNB angle, 3 ANB angle, 4 SN-GoGn angle, 5 U1-NA (angle), 6 U1-NA (linear), 7 L1-NB (angle), 8 L1-NB (linear), 9 Overbite, 10 Overjet, 11 UFH (Na-ANS), 12 LFH (ANS-Me), 13 Go-Gn*

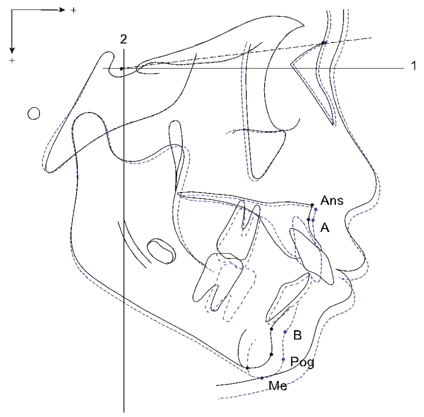


***Figure 2*** *Cranial base superimposition reference points and planes. Line 1: SN of T1 -7 degrees = X axis, Line 2: perpendicular line to line 1 at S point = Y-axis*

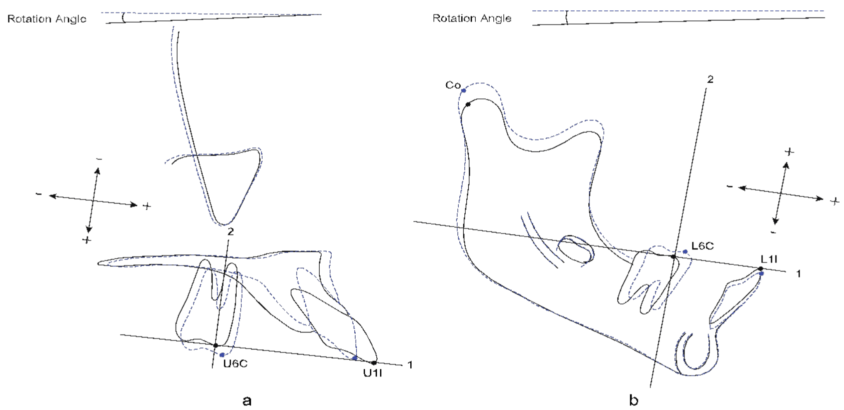


***Figure 3*** *Maxillary and mandibular superimposition reference points, planes and rotation angles. The occlusal plane of T1 served as X axis, while perpendicular line to occlusal plane at mesiobuccal cusp of first molar served as Y axis*

**Measurement error**

Cephalograms of ten patients were randomly selected for repeated all measurements by the first author (WS) after an interval of six weeks. The first and second readings were compared using the Intraclass correlation coefficient (ICC), and the ICC estimates using the 2-way mixed-effects model and their 95% confidence intervals were calculated to Test-Retest and Intrarater Reliability.

**Statistical analysis**

1. All data were analyzed with SPSS statistics software (version 22; IBM, Armonk, NY). Paired t-test was used to compare the pre- and post-treatments within the group.

2. One-way ANOVA and post-hoc comparison with the Scheffé test were used to analyze the differences among groups. The *P* value <0.05 was considered statistically significant. Wilcoxon signed ranks and Kruskal Wallis H tests were used to compare the significant differences within and between groups, respectively when the Kolmogorov-Smirnov normality test indicated that distribution of the variable was not normal.

3. Pearson's correlation coefficient was calculated to scrutinize the relation between significant changes of the mandibular position and other variables. Stepwise multiple linear regression was performed to determine the independent variables that played an important role on the mandibular position.

## Results

1. The ICC values showed excellent reliability with 0.986 (95% confidence interval, 0.978-0.994) for intrarater reliability. (Values less than 0.5, between 0.5 and 0.75, between 0.75 and 0.9, and greater than 0.90 were indicative of poor, moderate, good, and excellent reliability, respectively).[21]

2. Before treatment (Table 1), the Class II division 1 patients presented skeletal Class II malocclusion due to a retrusive mandible when compared with the norm.[22] There were no significant differences of the A-P position of the two jaws among the three groups, while the vertical position of the mandible considered from the SN-GoGn angle, as well as the lower face height (LFH), of the extraction group was significant greater than Class II traction group and headgear group, respectively. The extraction group had a more severe proclination and protrusion of the lower incisors, however overjet and overbite of the three groups were not significantly different.

***Table 1*** *Sample characteristics before treatment comprising : Age, skeleton and dental (T1)*

| | 1) Headgear group | | 2) Extraction group | | 3) Class II traction group | | Group differences | |
|---|---|---|---|---|---|---|---|---|
| | mean | sd | mean | sd | mean | sd | *P* value | Post hoc |
| Age (years) | 10.8 | 1.62 | 11.7 | 1.19 | 12.5 | 1.52 | <.000† | 1-2, 1-3 |
| SNA (degrees) (83±4) | 84.7 | 3.69 | 84.5 | 3.45 | 83.8 | 3.13 | 0.572 | ns |
| SNB (degrees) (79±3) | 77.2 | 3.39 | 77.3 | 3.19 | 77.2 | 3.26 | 0.993 | ns |
| ANB (degrees) (4±2) | 7.56 | 1.64 | 7.19 | 1.54 | 6.63 | 1.99 | 0.077 | ns |
| SN-GoGn (degrees) (34±6) | 33.6 | 3.56 | 35.6 | 3.51 | 32.9 | 4.61 | 0.017† | 2-3 |
| U1-NA (degrees) (28±4) | 29.3 | 5.22 | 29.9 | 6.43 | 27.2 | 9.11 | 0.295 | ns |
| U1-NA (mm) (6±2) | 4.84 | 2.21 | 6.28 | 2.55 | 5.55 | 3.11 | 0.100 | ns |
| L1-NB (degrees) (32±6) | 30.5 | 4.97 | 33.6 | 4.51 | 29.1 | 7.23 | 0.007 | 2-3 |
| L1-NB (mm) (6±2) | 7.86 | 1.51 | 9.97 | 1.92 | 7.42 | 2.00 | <.000† | 1-2, 2-3 |
| UFH (mm) | 53.3 | 2.53 | 54.7 | 3.35 | 54.7 | 3.87 | 0.143 | ns |
| LFH (mm) (67±4) | 65.5 | 3.60 | 68.5 | 4.77 | 66.3 | 5.27 | 0.029† | 1-2 |
| Go-Gn (mm) | 72.5 | 3.45 | 73.2 | 4.33 | 72.7 | 4.95 | 0.807 | ns |
| Overjet (mm) (2.3±1) | 6.95 | 0.35 | 6.36 | 0.38 | 6.86 | 0.37 | 0.443 | ns |
| Overbite (mm) (2.2±1) | 3.56 | 0.14 | 3.25 | 0.18 | 3.86 | 0.26 | 0.114 | ns |

†*Significant difference (p<0.05, ANOVA)*
*ns, No significant differences between groups.*

Alterations of skeletal and dental structures after treatment assessed by the linear and angular measurements (Table 2) indicated significant decrease of the SNA angle in all three groups while the SNB angle slightly increased in the headgear and Class II traction groups but decreased in the extraction group. The ANB angle significantly decreased in all three groups. The SN-GoGn angle increased significantly in the extraction and Class II traction groups but decreased in the headgear group. The three treatment modalities produced significant differences of incisor position and inclination except the position of lower incisor teeth in the headgear group.

***Table 2*** *Changes of skeletal and dental structures (T2-T1) evaluated by angular and linear measurements*

| | 1) Headgear group | | 2) Extraction group | | 3) Class II traction group | | Group differences | |
|---|---|---|---|---|---|---|---|---|
| | mean | sd | mean | sd | mean | sd | *P* value | Post hoc |
| SNA (degrees) | -1.17* | 1.69 | -1.02* | 1.67 | -0.70* | 1.58 | 0.662 | ns |
| SNB (degrees) | 0.19 | 1.70 | -0.14 | 1.32 | 0.16 | 1.92 | 0.407 | ns |
| ANB (degrees) | -1.58** | 1.19 | -0.88** | 1.68 | -0.80* | 1.53 | 0.063 | ns |
| SN-GoGn (degrees) | -0.49 | 5.28 | 0.78* | 2.14 | 1.31** | 2.22 | 0.302 | ns |
| U1-NA (degrees) | -7.25* | 5.25 | -15.4* | 9.18 | -5.70* | 7.28 | <.000†† | 1-2, 2-3 |
| U1-NA (mm) | -1.80* | 2.26 | -5.20* | 1.89 | -1.52* | 2.40 | <.000† | 1-2, 2-3 |
| L1-NB (degrees) | 2.53 | 6.57 | -8.56* | 6.12 | 8.38* | 9.11 | <.000† | 1-2, 1-3, 2-3 |
| L1-NB (mm) | 0.72 | 1.91 | -3.19* | 2.10 | 2.19** | 2.27 | <.000† | 1-2, 1-3, 2-3 |
| UFH (mm) | 4.13* | 2.95 | 2.98* | 1.92 | 2.22* | 2.42 | 0.013†† | 1-3 |
| LFH (mm) | 4.64* | 2.04 | 4.81* | 2.12 | 3.75* | 2.70 | 0.147 | ns |
| Go-Gn (mm) | 4.27* | 2.31 | 3.72* | 2.85 | 3.19** | 3.07 | 0.184 | ns |
| Overjet | -4.69** | 0.40 | -4.19** | 0.34 | -4.59** | 0.38 | 0.603 | ns |
| Overbite | -1.45** | 0.17 | -1.19** | 0.17 | -1.64** | 0.23 | 0.245 | ns |

**Significant difference within group (p<0.05, paired t-test)*

***Significant difference within group (p<0.05, Wilcoxon Signed Ranks Test)*

*†Significant difference between group (p<0.05, ANOVA)*

*††Significant difference between group (p<0.05, Kruskal Wallis H test)*

*ns, No significant group differences at .05 level.*

The treatment effects evaluated from the x-y coordinates and cranial base superimposition (Table 3) indicated significant forward displacement of the mandible (B, Pog, Me points) in the headgear and extraction groups. The most anterior position of the chin could be found in the headgear group followed by the extraction and Class II traction groups. In the vertical direction, both jaws moved downward significantly.

Alterations of the dental evaluated from both methods showed similar results. The upper and lower incisors of the extraction group were the most significantly retracted (Tables 2,3). When superimposed on the stable structures of the maxilla (Fig. 3), the maxillary incisor moved backward and downward while the molars moved forward and downward. Superimposition on the stable structures of the mandible (Fig. 3) indicated backward and upward displacements of the condylion point. The mandibular molars moved upward and forward while the significantly forward rotation of the mandible could be found more in the headgear group compared to the others (Table 3).

*Table 3 Changes of skeletal and dental structures (T2-T1) evaluated by the x-y coordinate system in each group*

| | | 1) Headgear group | | 2) Extraction group | | 3) Class II traction group | | Group differences | |
|---|---|---|---|---|---|---|---|---|---|
| | | mean | sd | mean | sd | mean | sd | *P* value | Post hoc |
| Horizontal change (mm) | | + anterior, - posterior | | | | | | | |
| Cranial base superimposition | ANS | 1.64* | 1.73 | 1.27* | 1.41 | 1.28** | 2.38 | 0.388 | ns |
| | A | 1.44* | 1.53 | 0.95** | 1.62 | 0.92* | 2.27 | 0.253 | ns |
| | B | 2.97* | 2.22 | 1.05 | 2.92 | 0.91 | 2.92 | 0.004†† | 1-2, 1-3 |
| | Pog | 3.73* | 2.42 | 1.63* | 3.06 | 1.02 | 3.40 | 0.001† | 1-2, 1-3 |
| | Me | 3.39* | 2.73 | 1.31* | 3.29 | 1.17 | 3.80 | 0.013† | 1-2, 1-3 |
| Maxilla superimposition | U1I | -1.22* | 2.43 | -4.75* | 1.78 | -0.84 | 3.16 | <.000† | 1-2, 2-3 |
| | U6C | 1.27* | 1.72 | 4.70* | 2.43 | 0.19 | 2.05 | <.000† | 1-2, 1-3, 2-3 |
| Mandibular superimposition | L1I | 0.55 | 2.18 | -3.45** | 3.38 | 2.41* | 2.26 | <.000† | 1-2, 1-3, 2-3 |
| | L6C | 1.23** | 1.90 | 3.17** | 1.60 | 1.16* | 1.50 | <.000†† | 1-2, 2-3 |
| | Co | -3.58* | 2.00 | -3.44* | 2.04 | -1.91** | 3.01 | 0.001†† | 1-3, 2-3 |
| Vertical change (mm) | | + extrusion, - intrusion | | | | | | | |
| Cranial base superimposition | ANS | 3.34* | 2.69 | 2.69* | 2.06 | 2.22* | 2.14 | 0.181 | ns |
| | A | 3.36* | 2.52 | 2.48* | 1.85 | 2.42* | 2.23 | 0.147 | ns |
| | B | 7.72* | 3.75 | 5.70** | 6.61 | 5.30** | 3.81 | 0.021†† | 1-3 |
| | Pog | 7.98* | 3.91 | 6.95* | 2.91 | 5.89* | 3.87 | 0.072 | ns |
| | Me | 8.47** | 4.15 | 7.36* | 3.00 | 6.17* | 4.27 | 0.042†† | 1-3 |
| Maxilla superimposition | U1I | 2.08* | 2.38 | 3.27* | 2.18 | 2.66* | 2.24 | 0.117 | ns |
| | U6C | 3.19** | 2.45 | 2.16** | 2.06 | 2.44** | 2.02 | 0.056 | ns |
| Mandibular superimposition | L1I | 1.16** | 1.46 | 1.78** | 1.34 | 0.95 | 4.24 | 0.012†† | 2-3 |
| | L6C | 2.48** | 1.14 | 2.50** | 1.09 | 2.86** | 4.29 | 0.813 | ns |
| | Co | 7.09** | 3.79 | 5.97* | 3.73 | 4.80* | 3.35 | 0.003†† | 1-3 |
| Rotation angle (degrees) | | + forward rotation, - backward rotation | | | | | | | |
| Maxilla superimposition | SN-7° | -0.22 | 1.17 | -0.5 | 1.84 | -0.48 | 1.97 | 0.541 | ns |
| Mandibular superimposition | SN-7° | 1.86 | 1.75 | 0.34 | 2.04 | 0.00 | 1.82 | <.000† | 1-2, 1-3 |

**Significant difference within group (p<0.05, paired t-test)*

***Significant difference within group (p<0.05, Wilcoxon Signed Ranks Test)*

*†Significant difference between group (p<0.05, ANOVA)*

*††Significant difference between group (p<0.05, Kruskal Wallis H test)*

*ns, No significant group differences at .05 level.*

The changes of mandibular positions (B, Pog, Me) and related hard tissue structures was evaluated by Pearson correlation. The only significant correlation structures were presented in Table 4. The mandibular rotation and the downward movement of the A point were the most correlated with the forward and downward movement of the mandible at the B, Pog, and Me points, respectively.

*Table 4* *Significant correlation between mandibular movement (B, Pog, and Me points) and related structures evaluated from Pearson correlation coefficient*

| | Horizontal | | | Vertical | | |
|---|---|---|---|---|---|---|
| | B | Pog | Me | B | Pog | Me |
| maxillary rotation | 0.414** | 0.395** | 0.407** | | | |
| mandibular rotation | 0.773** | 0.801** | 0.776** | | | |
| SNB angle | 0.473** | 0.435** | 0.420** | | | |
| ANB angle | -0.334** | -0.311** | -0.235** | | | 0.201* |
| SN-GoGn angle | -0.292** | -0.293** | -0.280** | | | |
| UFH | 0.255* | 0.349** | 0.274** | 0.489** | 0.711** | 0.759** |
| GoGn | 0.338** | 0.455** | 0.419** | 0.422** | 0.638** | 0.664** |
| Horizontal | | | | | | |
| Co | -0.442** | -0.510** | -0.461** | -0.332** | -0.532** | -0.566** |
| Ans | 0.471** | 0.472** | 0.498** | | 0.247* | 0.293** |
| A | 0.576** | 0.595** | 0.618** | | | 0.241* |
| Go | 0.413** | 0.353** | 0.356** | | 0.271** | 0.278** |
| U1I | 0.253* | 0.214* | 0.207* | | | |
| U6C | 0.209* | 0.284* | 0.249* | 0.209* | 0.252* | 0.260* |
| Vertical | | | | | | |
| Co | 0.382** | 0.498** | 0.444** | 0.517** | 0.641** | 0.653** |
| Go | -0.305** | -0.334** | -0.332** | 0.352** | 0.511** | 0.566** |
| U6C | -0.286** | -0.314** | -0.291** | 0.361** | 0.486** | 0.522** |
| Ans | | | | 0.523** | 0.775** | 0.797** |
| A | | | | 0.559** | 0.810** | 0.817** |
| U1I | | | | 0.295** | 0.467** | 0.481** |
| L1I | | | | | 0.287** | 0.284** |
| L6C | | | | | 0.262* | 0.255* |

* $P < .05$; ** $P < .01$

The stepwise linear regression analysis (Table 5) showed that mandibular rotation and horizontal change of the condylion were the independent variables for prediction of the antero-posterior movement of the B, pogonion and menton points. The regression equations were the following:

B (x) = -0.255 + 1.016 (mandibular rotation) - 0.387 (Co x),

Pog (x) = -0.268 + 1.168 (mandibular rotation) - 0.516 (Co x),

Me (x) = -0.41 + 1.227 (mandibular rotation) - 0.493 (Co x).

The regression equation (Table 5) for prediction the vertical movement of the B, pogonion and menton points were as follows:

B (y) = 1.284 + 0.885 (A y) + 0.405 (Co y),

Pog (y) = 2.189 + 1.071 (A y) + 0.29 (Co y),

Me (y) = 2.168 + 1.149 (A y) + 0.321 (Co y).

The vertical movements of the A point and the Co point are the major variables influencing the vertical movement of the chin point in all equations.

*Table 5* *Stepwise linear regression analyses of independent variables that predict horizontal and vertical movements of the mandible at Pog, Me and B points*

| | Independent variables | model | constant (α) | β1 | variable 1 | β2 | variable 2 | R | $R^2$ | F |
|---|---|---|---|---|---|---|---|---|---|---|
| Horizontal | B | 1 | 0.845 | 1.083 | mandibular rotation | - | - | 0.773 | 0.597 | 139.4* |
| | | 2 | -0.255 | 1.016 | mandibular rotation | -0.387 | Co x-axis | 0.843 | 0.710 | 113.8* |
| | Pog | 1 | 1.201 | 1.258 | mandibular rotation | - | - | 0.801 | 0.642 | 168.7* |
| | | 2 | -0.268 | 1.168 | mandibular rotation | -0.516 | Co x-axis | 0.896 | 0.802 | 188.8* |
| | Me | 1 | 0.994 | 1.131 | mandibular rotation | - | - | 0.776 | 0.603 | 142.7* |
| | | 2 | -0.41 | 1.227 | mandibular rotation | -0.493 | Co x-axis | 0.854 | 0.729 | 125.1* |
| Vertical | B | 1 | 2.812 | 1.244 | A y-axis | - | - | 0.559 | 0.312 | 42.7* |
| | | 2 | 1.284 | 0.885 | A y-axis | 0.405 | Co y-axis | 0.619 | 0.383 | 28.8* |
| | Pog | 1 | 3.283 | 1.328 | A y-axis | - | - | 0.810 | 0.656 | 179.4* |
| | | 2 | 2.189 | 1.071 | A y-axis | 0.29 | Co y-axis | 0.850 | 0.763 | 121.2* |
| | Me | 1 | 3.382 | 1.434 | A y-axis | - | - | 0.817 | 0.667 | 188.2* |
| | | 2 | 2.168 | 1.149 | A y-axis | 0.321 | Co y-axis | 0.859 | 0.738 | 131.2* |

**Significant difference (p<0.01, ANOVA)*

*Co x-axis, different of Co point in x-axis between T1 and T2 when superimposed at mandible (T2-T1)*

*A y-axis, different of A point in y-axis between T1 and T2 when superimpose at cranial base (T2-T1)*

*Co y-axis, different of Co point in y-axis between T1 and T2 when superimpose at mandible (T2-T1)*

## Discussion

The treatment modalities prescribed to the participants of this study were based upon the development of the dentition, site and severity of malocclusion. Prior to treatment (Table 1), the headgear group presented more protrusive maxilla, retrusive mandible, and severe incisal protrusion in the mixed dentition; consequently, orthopedic treatment was prescribed. The extraction group presented the most incisal protrusion in the permanent dentition; therefore, extraction of the four first premolars was carried out. The Class II traction group tended to have less SN-GoGn angle than those of the others with the latest dental development, extrusion of the mandibular molars from the traction should be beneficial for the vertical jaw discrepancy. All treatment modalities finally produced Class I molar and canine relationships as well as a more favorable jaw relationship.

The treatment effects were evaluated by two measurement cephalometric methods: linear and angular measurements and the x-y coordinate system. The former method enabled a comparison of treatment effect between the present study and others. The latter method was carried out for determining the horizontal and vertical changes of each reference point following overall superimposition and structural superimposition, as described by Björk and Skieller.[20,23]

All three treatment modalities could improve not only dentally but also skeletally by significant decrease in the SNA angle and the slight increase of the SNB angle except in the extraction group; however, there were no significant differences of the treatment effects among groups. The ANB angle presented a similar treatment effect. The SN-GoGn angle showed the bite opening effect in the extraction and Class II traction groups while it seemed to be stable in the headgear group; however, the changes were too small to present significant differences between groups.

The results supported previous studies that cervical headgear treatment could indicate minimal increase or no changes of the SNB angle when treated with a cervical headgear.[24-26] Meanwhile, evaluation from the x-y coordinate system revealed the most anterior position of the mandible with forward rotation (Table 3). The result was consistent with studies by Godt *et al*[5] and Cook *et al,*[27] who stated that proper usage of the headgear did not produce backward rotation of the mandible even in dolichocephalic patients. This study also supported the findings of Phan *et al.*[28] that the orthodontic treatment did not decrease mandibular forward rotation that worsens the facial profile. Some studies[4,29] found that headgear treatment could increase the mandibular plane angle. The different conclusions may come from the different evaluation methods.

In the extraction group, both upper and lower incisors, as well as the molars, changed significantly in a horizontal direction, because the extraction space allowed feasible correction of angulation and position of the teeth. Forward rotation of the mandible was also found but was significantly less than that of the headgear group. The SN-GoGn angle that showed the bite opening effect in this group could come from the surface change of lower border of the mandible due to normal facial growth.[20] Meanwhile, previous research[8,9] did not find a significant change of mandibular position when considered from the SNB angle.

The Class II traction group presented not only the least forward rotation of the mandible but also the least anterior position of the chin. The result did not support the previous suggestion30 "the least amount of mandibular plane angle, the more rotation of the mandible", since the Class II traction group who had the lowest SN-GoGn angle before treatment did not present more forward rotation of the mandible after treatment. The results indicated that the extrusion of the mandibular molar did not produce an adverse effect on mandibular rotation when prescribed to the patient who presented a normal or deep vertical growth pattern.

Although the results showed that the angular measurement (Table 2) could represent the changing in the horizontal direction in the same trend of the x-y coordinate superimposition method (Table 3), only the superimposition method showed the significant difference of the anterior position of the chin (B, Pog, and Me points) in the headgear group and the others. The SNA and SNB angles cannot interpret the changing of the A and B points in the vertical direction; meanwhile, the overall superimposition along the cranial base for the measurement of each point in relation to the Y-axis can manifest the different values among groups. The advantage of the superimposition method is that it can express the displacement of each reference point in the horizontal and vertical directions. According to the normality test, some of the variables were not normally distributed, indicating variations among the patients that should be concerned.

Stepwise linear regression was performed to evaluate the relationship among the change of mandibular position and related structures so that prediction of mandibular position after treatment could be achieved. The results (Table 5) indicated that mandibular forward rotation and horizontal growth of the condyle in the posterior direction played a major role in the forward movement of the mandible. The two factors involved around 77-89% of the variations in anterior movement of the three reference points of the mandible (B, Pog and Me points). The results confirmed the findings of several studies.[15,28,31,32] Björk and Skieller[31] showed that anterior movement of the chin was strongly related to the rotation of the mandible. Phan *et al.*[28] reported the horizontal displacement of the pogonion point significantly correlated with mandibular rotation (r=0.75). Buschang and Jacob[15] concluded that rotation of the mandible was the most important variable influencing chin position followed by horizontal growth of the condyle and horizontal movement of the glenoid fossa, respectively. LaHaye *et al.*[32] also reported that 90% of the variations in antero-posterior chin position could be explained by mandibular rotation combined with horizontal and vertical changes of the glenoid fossa and condyle. They also suggested that the treatment should control eruption or intrude posterior teeth for the maximum anterior position of the chin. However, the present study did not find the significance of the vertical change of the condyle on the anterior position of the chin and extrusion of the upper first molar in the growing patients did not deteriorate forward movement of the chin as the maximum movement of the mandible was found in the headgear group. Takahashi *et al.*[33] also reported that wearing cervical headgear significantly affected tongue pressure and anterior displacement of hyoid bone. The results were similar to the previous study[34] that the horizontal change of soft tissue chin depended on the different treatment modalities. For Class II growing patients, the mandibular growth could be expressed in maximum potential by the appropriate modality. Change of the vertical position of the chin could be predicted by the equation as well. Displacement of the A point and the condylion in vertical direction had a major influence on the inferior movement of the pogonion, menton, and B points. Vertical growth of the maxilla also played an essential role in chin position. Further studies should be undertaken to evaluate the relation between mandibular position after treatment and pharyngeal airway space.

## Conclusions

Treatment of Class II division 1 growing patients with headgear appliance, Class II traction or extraction of four premolars could affect the mandibular position. Orthopedic treatment with cervical headgear produced the most significant alteration of the mandibular position. Forward rotation of the mandible was the most important factor determining the antero-posterior mandibular position, followed by the horizontal growth of the condyle. Meanwhile, vertical growth of the maxilla and condyle had a major influence on the vertical mandibular position.

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