Title: Evaluation of effects of activator treatment on mandibular growth by analyzing components of condylar growth and mandibular rotation

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Key Word: Activator, mandibular total rotation, condylar growth, regional superimposition analysis

Abstract

Purpose: The objective of this study is to clarify the effects of activator treatment on mandibular growth in relation to condylar growth and total rotation of the mandible, and to investigate the relationships between the treatment responses and pretreatment facial morphology.

Materials and methods: Thirty Japanese girls with Class II division 1 malocclusion treated with activator were examined. Mean age at the start of treatment was 9.6 ± 1.6 years. Mean treatment duration was 19 ± 4 months. Lateral cephalograms obtained before and after treatment were used to analyze skeletal changes during treatment. Regional superimposition analysis was performed to evaluate activator effects by decomposing the mandibular growth into condylar growth and mandibular total rotation.

Results: The changes in intermaxillary relationships were significantly correlated with vertical condylar growth and mandibular total rotation ($P < 0.05$ and $P < 0.01$). The changes in the forward displacement of the mandible were significantly correlated with sagittal condylar growth and mandibular total rotation (P < 0.05 and P < 0.01). Vertical condylar growth and mandibular total rotation were significantly correlated with pretreatment mandibular morphology (P< 0.05 and P< 0.01).

Conclusion: Both the sagittal condylar growth and counterclockwise mandibular total rotation attributed to activator treatment contribute to forward displacement of the mandible. The activator effects are expected greater in patients with flat mandibular plane, small gonial angle, backwardly inclined mandibular ramus and long posterior facial height.

Introduction

When a growing patient is diagnosed with Class II malocclusion with a retrognathic mandible, the treatment plan first aims to change the amount and direction of mandibular growth using functional appliances [1]. Numerous reports have demonstrated favorable effects of functional appliances on mandibular growth in the treatment of Class II malocclusion [2-8]. Some systematic reviews [9,10] focused on the significant effects of functional appliances on mandibular growth. While studies have shown that functional appliance treatment can alter the growth of the mandible, it has been reported that the effects on growth are unpredictable [11,12] and whether functional appliances produce meaningful skeletal improvement in anterior-posterior chin position remains questionable [11,13,14].

Mandibular growth consists of a periosteal growth of cortical bone and an endochondral growth of the condyle. Active mandibular growth occurs in the condyle [15]. It has been suggested that mandibular morphology derived from periosteal growth is attributed to condylar growth [16,17]. Björk [15] reported that ramus height is increased, mandibular body is curved and gonial angle is small in vertical condylar growth, whereas ramus height is short, mandibular body is little curved, and gonial angle is large in sagittal condylar growth. It is possible that in the treatment of Class II malocclusion with a retrognathic mandible both of growth at the condyle and changes in mandibular morphology are related to improvements in sagittal jaw relationships. Therefore, to better understand the effects of functional appliances, it would be helpful to evaluate the effects on mandibular growth by separating growth at the condyle and change in mandibular morphology. Using a method based on Björk and Skieller [18], Haralabakis et al. [19] compared the effects of activator and cervical headgear by dividing treatment changes into four components; maxillary growth, mandibular translation (condylar growth), mandibular molar movement, and mandibular total rotation, which represents the rotation of the mandibular corpus during growth. However, it remains unknown how condylar growth and mandibular total rotation relate to jaw relationship changes in treatment using functional appliances. In addition, individually different direction, magnitude and timing of growth lead to variability in treatment response [20,21].

The objective of this study was to clarify the effects of activator treatment on mandibular growth in relation to condylar growth and mandibular total rotation, and to investigate the relationships between treatment responses and pretreatment facial morphology.

Materials and Methods

Subjects

Thirty Japanese girls with Class II division 1 malocclusion were examined. All subjects showed overjet of greater than 5 mm, full Class II or end-to-end molar relationships, and retrognathic mandible, and were treated with the activator.

The activator appliance consisted of a monobloc of acrylic with an upper labial bow. As construction bite, the mandible was postured forward in a Class I or overcorrected Class I molar relationship to stimulate growth of the condyle. All subjects were instructed to wear activator for 10-12 hours a day. Mean treatment duration was 19 ± 4 months.

Standardized lateral cephalograms were obtained before (T1; mean age, 9.6 ± 1.6 years) and after activator treatment (T2; mean age, 11.1 ± 1.6 years) from all subjects. The Ethics Committee of the dental college approved the protocols of this retrospective study (No. 214).

Cephalometric analysis

Fig. 1 and 2 show the cephalometric measurements employed in this study. In addition to conventional cephalometric variables, vertical linear measurements were performed by projecting the landmarks on a line perpendicular to the FH line through the sella.

In order to evaluate activator effects by decomposing T1-T2 changes into condylar growth and mandibular total rotation, a cephalometric analysis derived from the original analysis of Halazonetis [22] was performed. The regional superimposition method for this analysis was as described previously [22] and is briefly explained below.

The functional occlusal plane was used as the reference plane and the measurement point was set on the middle of the occlusal surface of the mandibular first molar. Total movement of the mandibular first molar from the initial (pre-treatment) to the final (post-treatment) position was decomposed into the following three components: (1) skeletal component, which describes the downward and forward translation of the mandible due to condylar growth; (2) dental component, which describes the dental movement of the molar relative to the mandibular alveolar bone; and (3) rotational component, which describes the total rotation of the mandible. Total rotation of the mandible was termed by Bjork and Skieller [18], and represents the rotation of the mandibular corpus.

Fig. 3 shows superimposition of the initial and final tracings on the mandibular internal stable structures including the contour of the mandibular canal, the labial cortical palate of the symphysis, the inner contour of the cortical plate at the lower border of the symphysis, any trabecular structure in the symphysis, and any developing tooth buds before the formation of roots [18]. By superimposing the two tracings, the mandibular molar on the initial tracing was transferred on the final tracing. The dental component was represented as the distance between measurement points of the molar transferred from the initial tracing and the molar of the final tracing. The total rotation of the mandible was measured as the angle between the SN lines of the initial and final tracings on the superimposition.

For separating mandibular growth into condylar growth and mandibular total rotation, on the superimposition of the initial and the final tracings on the SN line, the mandible of the final tracings with the initial mandibular molar was derotated by an equal amount but in the opposite direction to the above measured total rotation of the mandible (Fig. 4), using the center of the condyle as the rotation center. The rotational component was represented as the distance between measurement points of the molar on the derotated and the final tracings. Finally, the condylar growth component was represented as the distance between measurement points of the molar on the initial tracing and the transferred molar on the derotated tracing.

From the regional superimposition method, three components were assessed as 3 measurements: vector A, vector condylar growth; vector B, vector dentition; vector C, vector rotation. A graphical vector presentation of the measurements was shown in Fig. 5. The functional occlusal plane of the post-treatment (final) cephalogram was used as an x-axis for the sagittal direction. The y-axis was perpendicular to the functional occlusal plane through a measurement point of the first molar of the initial tracing. The x- and y-components of vectors A, B and C were measured based on this coordinate system.

Statistical methods

In order to assess the reproducibility of this method, 10 subjects were randomly selected. All angular and linear measurements at T1 and T2 and the superimpositional measurements were repeated at least 4 weeks after the first measurements. The combined error (S_e) and coefficient of reliability were calculated according to Houston [23]. Combined error (S_e) was estimated by the formula $S_e^2=\sum d^2/2n$, where d is the difference between the first and second measurements, and n is the sample size. The coefficient of reliability was estimated by the formula $1-S_e^2/S_t^2$, where S_t is the total variance of the measurement. For all measurements, the coefficient of reliability was above 98% and was considered to be within acceptable limits (Table 1 and 2).

Pearson's correlation coefficient or Spearman's rank correlation coefficient was used to evaluate the relationships between T1-T2 changes in the angular or the linear measurements and each component of the vectors from the regional superimposition method. The relationships of each component of the vectors to the pretreatment (T1) cephalometric measurements were also evaluated. The level of statistical significance was set at $P < 0.05$.

Results

Table 3 and 4 show the means and standard deviation of regional superimpositional and cephalometric measurements, respectively.

Table 5 shows the correlation coefficients between the T1-T2 changes of cephalometric measurements and regional superimpositional measurements. The changes in ANB angle, convexity and A-B plane angle, which represent sagittal intermaxillary relationships, were significantly correlated with the y-component of vector A of the condylar growth and both the x- and y-components of vector C of mandibular rotation ($P < 0.05$ and $P < 0.01$). The changes in SNB angle, SNP angle and facial angle, which represent the anterior-posterior position of the mandible, were significantly correlated with the x-component of vector A and both the x- and y-components of vector C ($P < 0.05$ and $P < 0.01$). Changes in SNB angle were also significantly correlated with the y-component of vector A ($P < 0.05$).

Changes in the Frankfort-mandibular plane angle, ramus angle and GZN showed significant correlations with both the x- and y-components of vector C ($P < 0.05$ and $P < 0.01$). For vertical measurements, the changes in N-Me and Me-ANS were significantly correlated with the y-component of vector A ($P < 0.01$), whereas the changes in Go-Ar and S-Go were significantly correlated with the y-component of vector A and both the x- and y-components of vector C ($P < 0.05$ and $P < 0.01$).

Table 6 shows the correlation coefficients between the pretreatment cephalometric measurements, and condylar growth and mandibular total rotation of the regional superimpositional measurements. For vector A of condylar growth, the y-component showed significant correlations with gonial angle, ramus angle, GZN, N-Me, Me-ANS and S-Go ($P < 0.05$ and $P < 0.01$). S-Go was also significantly correlated with the x-component of vector A ($P < 0.05$). For vector C of mandibular rotation, both the x- and y-components were significantly correlated with the Frankfort-mandibular plane angle, gonial angle and S-Go ($P < 0.05$ and $P < 0.01$). The x-component of vector C also showed significant correlations with N-Me ($P < 0.05$). The y-component was also significantly correlated with ramus angle and GZN ($P < 0.05$).

Discussion

This study used regional superimposition analysis, introduced by Halazonetis [22] in order to evaluate the effects of activator treatment. From the results of regional superimposition analysis (Table 3), the mean amounts of the x-component of vectors A and C were 1.91 mm and 0.59 mm, respectively, resulting in 2.50 mm of forward change in mandibular growth. The mean amounts of the y-component of vectors A and C were 6.67 mm downward and 1.30 mm upward, respectively, resulting in 5.37 mm of downward change during treatment. The results of Haralabakis et al. [19] using regional superimposition analysis showed that the mean amounts of the x-component of the vectors A and C were 2.18 mm and 0.55 mm forward during activator treatment, respectively, and that the mean amounts of the y-component of vectors A and C were 6.07 mm downward and 1.10 mm upward, respectively. The treatment changes here are similar to those of activator treatment reported by Haralabakis et al. [19].

With regard to the relationship between vector C, which represents the total rotation of the mandible, and cephalometric changes, both the x- and y-components of vector C showed significant correlations with the changes in some cephalometric measurements. This indicated that there is no need to divide the vector C into x- and y-components when considering its relationships with cephalometric changes. As vector C is considered to show an upward and forward total rotation of the mandible to the cranial base, the changes in cephalometric measurements were found to be related to counterclockwise mandibular total rotation.

The sagittal component of the condylar growth and the rotational component of the mandible were significantly correlated with advancement of the mandible during activator treatment (Table 5). It is known that the mandibular forward position due to construction bite for the activator stimulates condylar growth [24]. Forward total rotation of the mandible naturally takes place during childhood and adolescent growth [14-17,25], and rotation induces advancement of the mandible [15,16]. The present results confirmed that both the sagittal component of condylar growth and the counterclockwise total rotation of the mandible attributed to activator treatment contribute to forward displacement of the mandible.

The vertical component of condylar growth and the rotational component of the mandible were significantly correlated with the correction of sagittal intermaxillary relationships (Table 5). As described above, the total rotation of the mandible with activator treatment is related to advancement of the mandible; thus, mandibular rotation results in the correction of sagittal intermaxillary relationships. The relationships of vertical condylar growth to sagittal intermaxillary relationships could be considered as below.

The vertical component of condylar growth was also significantly correlated with the changes in posterior facial height (Table 5). Many studies have reported that vertical condylar growth increases posterior facial height, and then mandibular total rotation takes place [15,16,26]. In this study, statistically significant relationships between the increase in posterior facial height and counterclockwise total rotation of the mandible, which contributed to the correction of sagittal jaw relationships, were revealed (Table 5). Thus, the vertical condylar growth attributed to the activator treatment appears to result in the improvement of jaw relationships.

The rotational component of the mandible was significantly correlated with changes in mandibular morphology (Table 5). The counterclockwise total rotation of the mandible was related to the flattening of the mandibular plane and the backward inclination of the ramus plane. This apparently coincides with the description of growth changes in mandibular morphology reported by Björk [15].

The comparison of condylar growth and mandibular total rotation with pretreatment facial morphology (Table 6) showed that the amounts of the rotational component of mandibular growth and the vertical component of condylar growth due to activator treatment were larger when the initial gonial angle was smaller, the initial mandibular ramus was more backward inclined, and the initial anterior and posterior facial heights were longer. The amount of the rotational component of mandibular growth was also larger when the initial mandibular plane was flatter. The correlations between mandibular total rotation and vertical condylar growth with initial cephalometric measurements were almost the same because vertical condylar growth increases posterior facial height and then mandibular rotation occurs, as described above [15,16,26].

The cephalometric variables, other than gonial angle, with significant correlations to condylar growth and/or mandibular total rotation at the pretreatment stage also showed significant correlations with condylar growth and mandibular total rotation in their T1-T2 changes. As the patient pretreatment face is considered to be strongly influenced by individual growth characteristics, it is possible that the growth changes due to activator treatment are influenced by the individual growth characteristics of the face, which results in variability of treatment responses.

From a clinical point of view, the present results suggest that greater activator effects are expected when growing Class II patients have a flat mandibular plane, small gonial angle, backwardly inclined mandibular ramus, and long posterior facial height. Further studies may establish multiple regression equations, including potential predictors of cephalometric variables, thus enabling identification of patients who may benefit from activator treatment.

Conclusions

Regional superimposition analysis confirmed that both sagittal condylar growth and counterclockwise rotation of the mandible attributed to activator treatment contribute to forward displacement of the mandible. The vertical condylar growth attributed to activator treatment increases posterior facial height, which induces mandibular total rotation, and appears to result in the improvement of jaw relationships. The present results suggest that the effects of activator is greater when growing Class II patients have a flatter mandibular plane, smaller gonial angle, backwardly inclined mandibular ramus and longer posterior facial height.

Conflict of interest

The authors have no conflict of interest to disclose.

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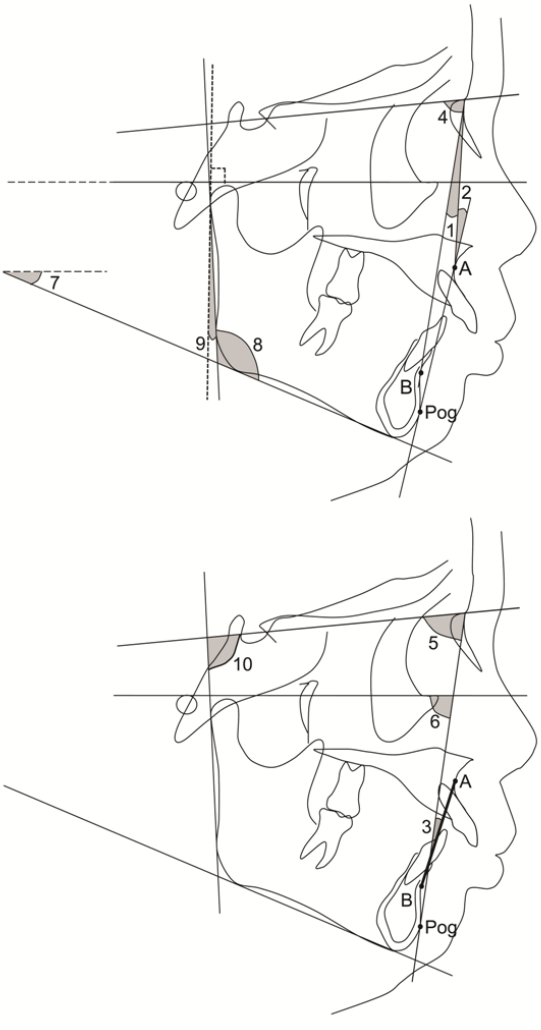


1. ANB
2. Convexity
3. A-B plane
4. SNB
5. SNP
6. Facial angle
7. Mandibular pl. to FH
8. Gonial angle
9. Ramus angle
10. GZN

Fig. 1

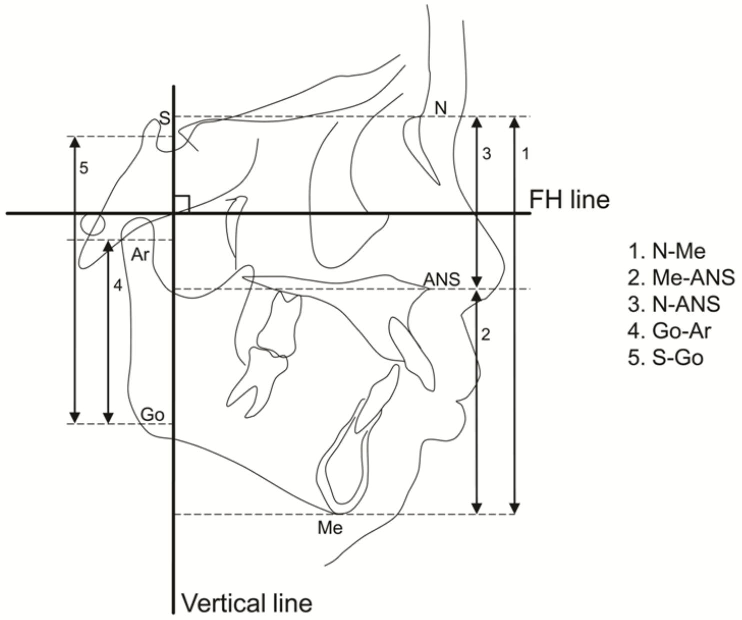

S
N
5
3
1
FH line
Ar
4
ANS
2
Go
Me
Vertical line
1. N-Me
2. Me-ANS
3. N-ANS
4. Go-Ar
5. S-Go

Fig. 2

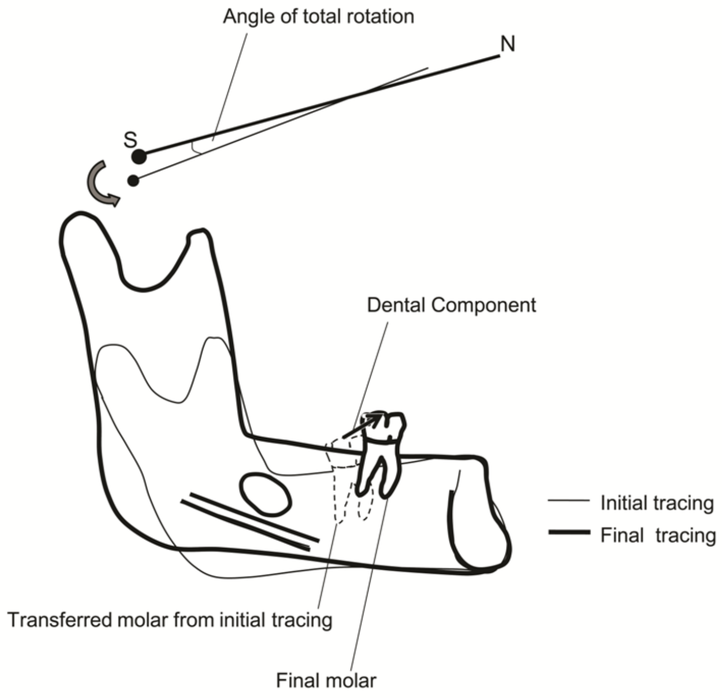
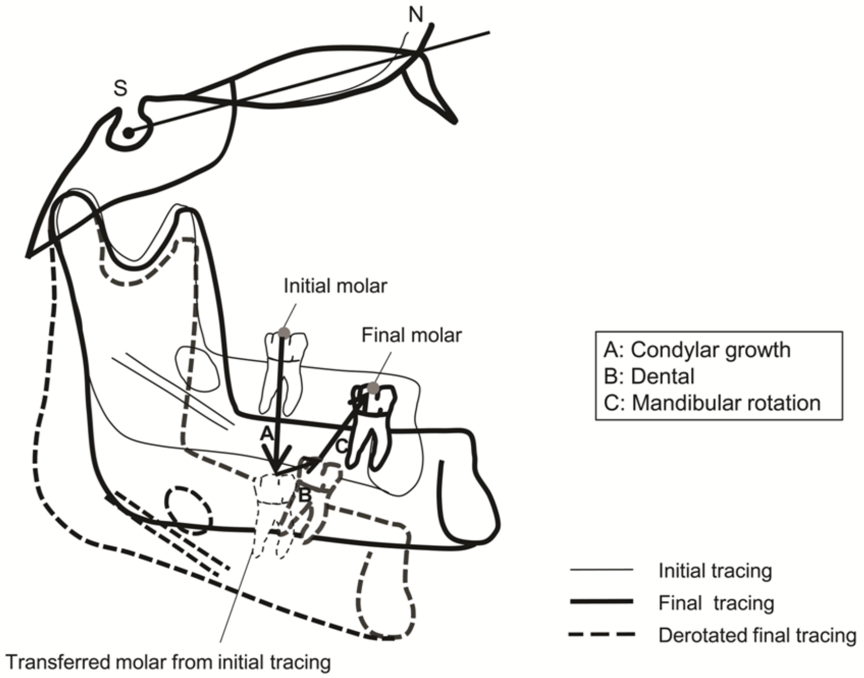

Angle of total rotation
N
S
Dental Component
Initial tracing
Final tracing
Transferred molar from initial tracing
Final molar

Fig. 3



S
N
Initial molar
Final molar
A: Condylar growth
B: Dental
C: Mandibular rotation
A
B
C
Initial tracing
Final tracing
Derotated final tracing
Transferred molar from initial tracing

Fig. 4

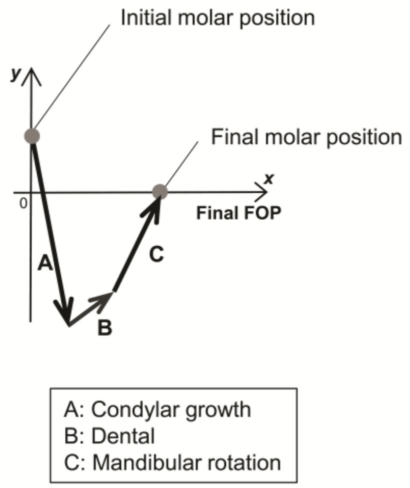

Initial molar position
y
Final molar position
x
0
Final FOP
A
C
B
A: Condylar growth
B: Dental
C: Mandibular rotation

Fig. 5

Legends to Figures

Fig. 1 - Cephalometric angular measurements.

Fig. 2 - Cephalometric vertical liner measurements. Vertical line was perpendicular to the FH line through the sella. All points were projected parallel on the vertical line. Each distance between the two projected points was measured.

Fig. 3 - Superimposition of initial (pre-treatment) and final (post-treatment) tracings on stable mandibular internal structures. The dental component and an angle of total rotation are represented.

Fig. 4 - Superimposition of initial and final tracings on cranial base. On superimposition, the mandible on the final tracing with the initial mandibular molar was derotated using the center of the condyle as the rotation center. The rotational component, the dental component, and the

condylar growth component are represented.

Fig. 5 - Graphic vector presentation of movement of mandibular first molar. FOP; functional occlusal plane.