Original Article

A Special Method of Predicting Mandibular Growth Potential for Class III Malocclusion

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Abstract: The purpose of this study was to establish an equation to predict the mandible growth potential (GP) for Class III malocclusion on the basis of the analysis of the cervical vertebrae in a single cephalometric radiograph and to compare its predictive accuracy with other methods. Data comprised two groups each with 22 Japanese girls. Group A was examined to construct the prediction equation. Group B served to compare the predictive accuracy with the GP method and the method of Mito et al (MM). The following results were obtained: (1) an equation was determined to obtain mandible GP on the basis of measurements in the third and fourth cervical vertebral bodies and (2) the average errors between the predicted increment and the actual increment for each method were 1.45 mm for the equation, 2.91 mm for the GP method, and 2.48 mm for the MM. These results suggest that using cervical vertebral measurements might allow predicting the mandible GP length for Class III malocclusion. (*Angle Orthod* 2005;75:191–195.)

Key Words: Class III; Growth; Mandible; Cervical vertebrae

INTRODUCTION

A Class III malocclusion is a common malocclusion in orthodontic clinics in Japan. Although the prevalence of Class III malocclusion in the Japanese has not been studied in detail, estimates of the frequencies of anterior crossbite and edge-to-edge incisor relationships in Japanese range from 2.3–13% to 2.7–7.4%, respectively.[1–3] If the frequencies of these two manifestations of Class III malocclusion are combined, a substantial percentage of the Japanese population has characteristics of Class III malocclusion.

Several studies have shown that Class III malocclusions are characterized by a longer than normal mandible.[4–6] Therefore, predicting the mandibular growth potential (GP) for Class III malocclusions as early as possible is useful for estimating the severity and deciding the treatment plan of the malocclusion.

GP is defined as the increment from the present length to the final length. Based on hand-wrist radiographs, five methods are available to predict mandible GP using skeletal maturation as an indicator.[7–9] These include (1) the ossification events method, (2) the GP method (GPM), (3) the growth percentage method, (4) the growth chart method, and (5) the multiple regression method. However, these methods require expert knowledge and operator time, and their accuracy is not very high.

In the past three decades, the relationship between cervical vertebral maturation and mandible growth has received increasing attention in the orthodontic field. Various cephalometric studies have described the increment in mandible length associated with specific maturational stages in the cervical vertebrae.[10–19] However, the quantitative relation between mandible GP and cervical vertebrae is still not fully explored in the literature.[11,12,16]

Mito et al[18,19] attempted to establish a formula to predict mandible GP on the basis of cervical vertebral bone age[18], but their formula determined growth only for Class I and II malocclusions (ANB 4.71 $\pm$ 1.73°). The quantitative relation between the mandible GP in the Class III malocclusions and cervical vertebrae has not been explored. Hence, a special formula for Class III malocclusions is needed.

The purposes of this study were to establish an easy way to use cervical vertebral bone to predict mandible growth for Class III malocclusions and to compare the predicting accuracy with the GP method and the method of Mito et al (MM).[19]

MATERIALS AND METHODS

The subjects of this study were 44 girls from Japan selected from the files of Division of Orthodontics, Graduate School of Medical and Dental Sciences, Niigata University,

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TABLE 1. Composition of Group A and Group B

	Group A (n = 22)	Group B (n = 22)	*P*
Initial age (y)	8.62 ± 0.61	8.45 ± 0.87	.765
Final age (y)	18.57 ± 0.34	18.64 ± 0.43	.889
Ar-Pog (initial)	98.23 ± 4.10	98.45 ± 3.43	.492
Ar-Pog (final)	118.34 ± 4.98	118.79 ± 4.56	.568

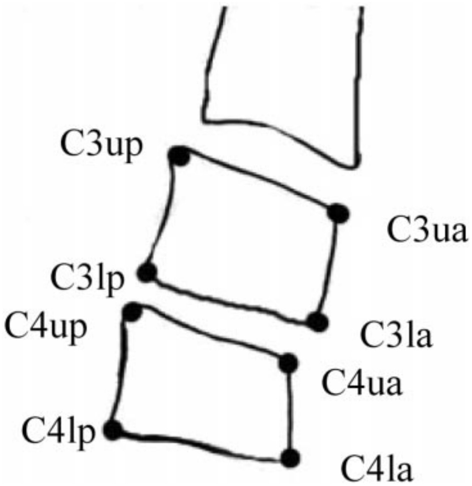

FIGURE 1. Cephalometric landmarks for the quantitative analysis of C3 and C4 in this study.

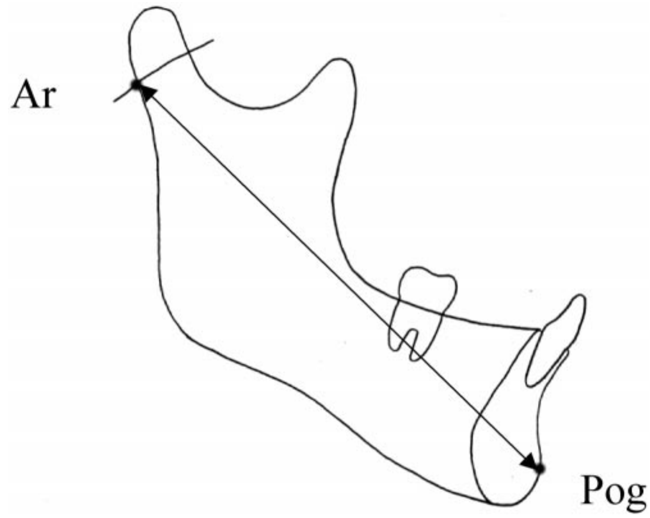

FIGURE 2. Cephalometric landmarks for measurements of mandible length. Ar, articulare; Pog, pogonion.

Japan. Group A was examined to construct the prediction equation, and group B served to compare the predictive accuracy of the equation established with other methods (Table 1).

All subjects fulfilled the following criteria: female, Class III molar relations; no systemic disease that could affect general development; no orthopedic treatment was used (eg, chin cup, headgear).

The following radiographs were obtained for each patient: (1) hand-wrist and cephalometric radiographs taken in the same date in the CVMS I period (initial stage) and (2) cephalometric radiographs taken in the 18-year-old (final stage). All radiographs were obtained with an object-film distance of 15 cm and cathode-object distance of 150 cm.

The CVMS I stage was decided according to the definition of Baccetti et al,[11] ie, CVMS I: the lower borders of the vertebrae C2, C3, and C4 are flat, with the possible exception of a concavity at the lower border of C2 in almost 50% of the cases. The bodies of the both C3 and C4 are trapezoid in shape.

Group A: establishing the equation

Cephalometric analysis. Cervical vertebral bodies (Figure 1)—on the lateral cephalometric radiographs, the body of the third cervical vertebra (C3) and the body of the fourth cervical vertebra (C4) were selected because C3 and C4 could be observed even when a thyroid-protective collar was worn during radiation exposure. The following points described by Baccetti et al[11] and the following lines for the description of the morphologic characteristics of the cervical vertebral bodies were traced by pencil and measured with micrometer calipers:

C3up, C3ua—the most superior points on the posterior and anterior borders of the body of C3;
C3lp, C3la—the most posterior and anterior points on the lower border of the body of C3;
C4up, C4ua—the most superior points on the posterior and anterior borders of the body of C4;
C4lp, C4la—the most posterior and anterior points on the lower border of the body of C4;
AH3, AH4 (anterior vertebral body height of the C3 and C4)—the distance between C3ua and C3la and the distance between C4ua and C4la;
PH3, PH4 (posterior vertebral body length of the C3 and C4)—the distance between C3up and C3lp and the distance between C4up and C4lp;
AP3, AP4 (anteroposterior vertebral body length of the C3 and C4)—the distance between C3la and C3lp and the distance between C4la and C4lp.

Mandibles (Figure 2)—articulare to pogonion (Ar-Pog) was used to represent the mandible length. GP was calculated by the Ar-Pog differences between final and initial stages. GP (mm) = Ar-Pog (final) − Ar-Pog (initial).

To determine the measurement errors, 20 of the traced and measured cephalometric radiographs were obtained again 10 days later. The differences between the measurements were evaluated using a Student's *t*-test with a paired design.

Statistical analysis. The data obtained from the group A were analyzed by statistical software SPSS Version 10.0 for

TABLE 2. The Measurements of C3, C4, in Group A

	Initial Stage	Final Stage	*P*
AH3 (mm)	7.54 ± 0.82	16.12 ± 4.76	00.0**
PH3 (mm)	9.13 ± 1.12	15.67 ± 1.83	00.0**
AP3 (mm)	13.41 ± 1.24	14.54 ± 1.23	00.0**
AH4 (mm)	7.34 ± 1.45	15.87 ± 1.32	00.0**
PH4 (mm)	9.23 ± 1.19	15.21 ± 1.97	00.0**
AP4 (mm)	12.13 ± 0.87	15.01 ± 1.79	00.0**

** $P < .01$.

Windows (SPSS Inc., Chicago, Ill). In the multiple regression analysis, the values of the GP were used as dependent variables, and the values of the cervical vertebrae at CVMS I were used as independent variables. No adjustments were made for the 11% enlargement factor. The selections of the independent variables were completed according to the stepwise method.

Group B: comparing the predictive accuracy

The error between the predicted GP and actual growth was used to represent the predictive accuracy. In group B, we used GPM, the MM, and our equation to predict mandible GP and then compared with the actual GP. The Student's *t*-test was used to compare the predictive accuracy. GPM was selected because it was considered as one of the best method to predict mandible GP based on the hand-wrist bone age.[20] MM was selected because it was suggested suitable for all classes of malocclusions.[19] We used the GPM of Sato et al,[20] which includes Cd-Gn to represent mandible length. The bone age used as a parameter was calculated by RUS[21] based on hand-wrist radiographs in the GPM.

The following linear equation[20] was used to determine GP:

$$\text{GP (mm)} = -2.60 \times \text{bone age} + 37.29.$$

As for the MM,[18,19]

$$\text{cervical vertebral bone age} = -0.20 + 6.20 \times \text{AH3/AP3} + 5.90 \times \text{AH4/AP4} + 4.74 \times \text{AH4/PH4 and}$$

$$\text{GP (mm)} = -2.76 \times \text{cervical vertebral bone age} + 38.68.$$

We used their definition[19] of AH3, AH4, PH4, and AP4 and calculated the error between the predicted GP and the actual growth.

RESULTS

Measurements

Means and standard deviations and the results of Student's *t*-test between initial and final stages are shown in Table 2. All the measures in CVMS I were significantly smaller than those in final stage. The cervical vertebrae exhibited significant growth.

Measurement error

The size of the combined method error (ME) was calculated as $\text{ME} = \sqrt{\Sigma d^2/2n}$, where d is the difference between two registrations of a pair and n is the number of double registrations. No significant differences were found between the measurements at the different occasions ($P <$ .05). The standard deviations ranged from 0.20 to 0.32 mm.

Multiple regression analysis

We selected six factors as independent variables and GP as the dependent factor.

The equation (SPE) is:

$$\text{mandible GP (mm)} = 61.01 - 1.31 \times \text{AH3} - 1.25 \times \text{PH3} - 0.73 \times \text{AP3} - 1.68 \times \text{AH4}.$$

In the present study R^2 was 52.6%; R^2 indicated the portion of the variability of the dependent variables. The combination of the AH3, AH4, AP3, and PH3 explained the variability of GP by 52.6%.

Predictive accuracy

Tables 3 and 4 list average errors between predicted and actual GP and average errors of the absolute value in each prediction method. Average errors ranged from 0.41 to 1.87 mm, and average errors of the absolute value were between 1.45 and 2.91 mm. The average error of SPE was the smallest, whereas the average error of GPM was the largest. The accuracy of SPE had significant differences compared with the GPM and MM.

DISCUSSION

The purpose of this study was to provide the orthodontist with an easy tool to help determine the mandibular GP of Class III malocclusion. This was to be accomplished by analyzing the changes of the cervical vertebrae on the lat-

TABLE 3. Average Predicted Errors Between This Method (SPE) and the Growth Potential Method (GPM) in Group B

	SPE	GPM	*P*
Average error (mm)	0.41 ± 2.03	1.87 ± 2.37	.022*
Average error (mm) (absolute value)	1.45 ± 1.45	2.91 ± 1.45	.012*

* $P < .05$.

TABLE 4. Average Predicted Errors Between This Method (SPE) and the Method of Mito et al (MM) in Group B

	SPE	MM	*P*
Average error (mm)	0.41 ± 2.03	−1.6 ± 2.23	.048*
Average error (mm) (absolute value)	1.45 ± 1.45	2.48 ± 2.32	.044*

* $P < .05$.

eral cephalometric radiograph of the patient's head, a type of film used routinely in orthodontic diagnosis. If successful, the orthodontist would have a reliable diagnostic tool to aid in formulating treatment options.

Sample and measurements

In this study, Japanese girls were examined because of sex-dependent differences with regard to the timing of morphological changes in cervical vertebral bodies.[10] Baccetti et al[11] showed that only the shape change of C2, C3, and C4 was enough to show skeletal maturation. However, C2 shows very little morphological change and was difficult to measure. Therefore, C3 and C4 were selected.

According to the study of Mito et al,[18,19] AH3, 4 was defined as the distance from the top of front part to a tangent of the lower part. PH3, 4 was defined as the distance from the top of back part to a tangent of the lower part. AP3, 4 was defined as the anteroposterior distance at the middle of cervical vertebral body. However, GP has a lower correlation with AH3/AP3, AH4/AP4, and AH4/PH4 ($r <$ 0.25) than with AH3, 4, PH3, and AP3 ($r >$ 0.42) defined by us in the Class III malocclusions. The possible reason may be that AP, AH, and PH grew at approximately same rate in the CVMS I stage. AH3/AP3, AH4/AP4, and AH4/PH4 may show less change than mandibular growth. In our study, AH3, 4; PH3, 4; and AP3, 4 were selected as independent values.

Mandible length is often defined as the linear distance between the Co (the most superior point on the head of the condyle) and the pogonion (Pog). Some reports have shown that Co cannot be accurately and consistently located on the closed-mouth later cephalogram.[22–24] Haas et al[25] examined the validity of articulare for mandible length measurements. According to his results, Ar is a good substitute for Co when measuring overall mandible length. In this study, we compared the GP other than the final length. There will be no difference in using the Co-Pog, Ar-Pog, or Cd-Gn for the same patient if the point was located correctly. Ar-Pog was used in this study because it is easily located.

Statistical methods for the equation

A stepwise regression analysis was used in this research to define prediction models that could be used to forecast individual future mandibular growth. The stepwise method was used to select the explanatory variables. In the stepwise procedure, the variable that has the highest correlation with the dependent variable is selected first, and the next variable considered is the one that significantly increases R^2 by largest amount. The procedure continues until there are no remaining independent variables that provide a significant increase in R^2, and the regression coefficients of the selected variables are described to formulate an equation.

The variability of the dependent variable that could be the regression equation is characterized by R^2, which is considered high for biological data when it ranges from 30% to 67%.[26] In the present study, R^2 was 52.6%. According to the statistical rule, the number of samples must be at least twice as many as the number of independent variables.[27] The present sample consisted of 22 cases. This was a satisfactory number to make the regression coefficients and the R^2 values truly representative of the actual population.

The predictive accuracy

Ngan et al[28] compared the skeletal growth changes between Class II, division 1 and Class I subjects. Mandibular growth was found to be smaller in Class II, division 1 malocclusions than in Class I malocclusions. Several reports[29,30] have shown that Class III malocclusion may have more growth than the other two malocclusion classes. According to the study of Mito et al,[19] their formula for using cervical vertebral bone age to calculate the GP was determined from Class I and Class II patients (ANB 4.71 ± 1.73°). The smaller GP in Class II was not noted. The GPM does not pay any attention to the growth among the different class malocclusions. On the other hand, SPE was derived from Class III malocclusions, and the accuracy was tested with Class III malocclusions. This reason may ensure the highest predictive accuracy of SPE.

For evaluating skeletal maturation, the anatomical parameters of concavity of the lower border have been demonstrated to be better than the height and shape of the vertebral bodies.[16] According to the study of Mito et al,[18] their formula can be used for different CVMS stages to calculate the cervical bone age, but there are no parameters of concavity in their formula, and the parameter for cervical bone age may need to be selected again. In this study, the CVMS I stage was used as the initial age. The characteristics of C3 and C4 in CVMS I in the lower borders are flat. Only dimensional changes in this stage may lead to the accuracy of SPE higher than the MM.

Another reason that the accuracy of the SPE is higher than the GPM could be that the GPM was determined by analyzing bone age based on hand-wrist radiographs. In analyzing hand-wrist radiographs, nine stages (A–I) are typically used to show bone maturity. Using discontinuous values to predict continued values of mandible growth likely led to the lower predictive accuracy of GPM.

The last reason that the accuracy of the SPE is higher than that of the GPM may be that the mandibular is located next to the cervical vertebral bone. The time of its bone formation is closer to that of the cervical vertebral bone than to the hand-wrist bone. The mandibular length would have a closer relationship with cervical vertebral bone than with hand-wrist bone in growth.

All the subjects of this study can be classified as skeletal Class III. Therefore, SPE can be applied to skeletal Class III. Because Class III malocclusion is very common in Asia,[31–34] we intend to verify whether our method can be applied to other races. To be clinically useful, it may be necessary to improve the predictive accuracy by increasing the number of subjects in future studies.

CONCLUSIONS

We established a special equation for Class III malocclusions to predict mandible growth and compared it with other predictive methods. The equation might be one possible method for predicting the mandible GP based only on a single cephalometric radiograph.

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