

## Original Article

# Prediction of Individual Mandibular Changes Induced by Functional Jaw Orthopedics Followed by Fixed Appliances in Class II Patients

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### ABSTRACT

**Objective:** To identify pretreatment cephalometric variables for the prediction of individual mandibular outcomes of functional jaw orthopedics (FJO) followed by fixed appliances in Class II patients treated at the peak in mandibular growth.

**Materials and Methods:** The study was performed on 51 subjects (24 females, 27 males) with Class II malocclusion. First-phase therapy was accomplished with a twin block in 16 subjects, a stainless steel crown Herbst in 15 subjects, and an acrylic splint Herbst in 20 subjects. Lateral cephalograms were available at the start of treatment with FJO and at the completion of fixed appliance therapy. All subjects received FJO at the peak in mandibular growth (CS 3 at T1). Individual responsiveness to Class II treatment including FJO was defined on the basis of the T2-T1 increment in total mandibular length (Co-Gn) when compared with untreated Class II subjects.

**Results:** Discriminant analysis identified a single predictive parameter (Co-Go-Me°) with a classification power of 80%. Pretreatment vertical and sagittal parameters were not able to improve the prediction based upon the mandibular angle.

**Conclusions:** A Class II patient at the peak in skeletal maturation (CS 3) with a pretreatment Co-Go-Me° smaller than 125.5° is expected to respond favorably to treatment including FJO. A Class II patient at CS 3 with a pretreatment value for Co-Go-Me° greater than 125.5° is expected to respond poorly to treatment including FJO.

**KEY WORDS:** Class II malocclusion; Functional appliances; Cephalometric analysis

### INTRODUCTION

A wide range of functional/orthopedic appliances aimed to stimulate mandibular growth by forward posturing of the mandible is available for the correction of Class II disharmony,<sup>1</sup> a type of malocclusion that affects one third of the North American population.<sup>2-4</sup> Systematic reviews of the literature<sup>5,6</sup> on the outcomes of functional jaw orthopedics (FJO) in Class II malocclusion have shown a substantial variability of reported results. These differences have to be ascribed mainly

to the type of appliance used (as related to the duration of active treatment needed to achieve a Class II correction, and to the patient's compliance required) and to the timing of intervention.

Among the different types of functional appliances, the Herbst and the twin block demonstrated the greatest efficiency in Class II correction.<sup>6</sup> As for treatment timing, significantly greater effects of FJO have to be expected when treatment is carried out at the peak in mandibular growth as detected by a reliable indicator of skeletal maturity (hand and wrist analysis, cervical vertebral maturation method, analysis of increases in staturel height) when compared to the outcomes of treatment performed before or after the growth spurt.<sup>7-11</sup>

In addition to the variability in treatment response among different studies, a similarly wide variability can be assessed within individual studies, ie, a significant variability in the response of individual patients to the same treatment protocol. Hence the clinical interest of those investigations aimed to identify pretreatment cephalometric determinants of successful FJO.

Most of the available studies have analyzed factors for individual success of FJO in terms of occlusal cor-

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rection (correction in overjet and molar relation).<sup>12-17</sup> Patel and coworkers<sup>17</sup> have discriminated successful and unsuccessful outcomes of FJO on the basis of the amount of skeletal change between the maxilla and the mandible (ANB angle). An alternative approach to the evaluation of treatment outcomes following the use of functional/orthopedic appliances in Class II malocclusion may refer to the assessment of increases in mandibular dimensions. As a matter of fact, the primary objective of FJO in Class II patients with mandibular skeletal retrusion is the enhancement of mandibular growth, ie, the supplemental amount of mandibular growth with respect to untreated Class II subjects. An additional limitation of existing literature on pretreatment indicators of therapeutic outcomes of FJO is the lack of information about the individual skeletal maturity of treated patients at the start of therapy.

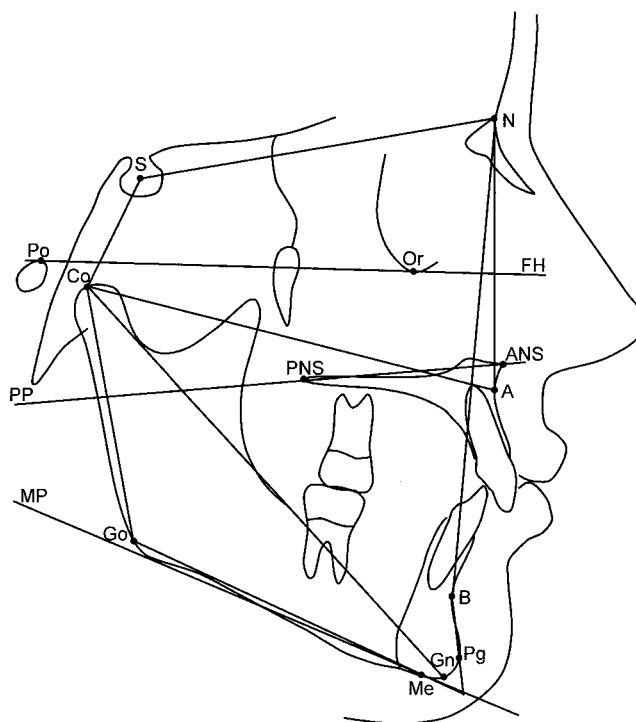
The aim of this cephalometric investigation was to identify pretreatment parameters for the prediction of individual mandibular changes induced by functional jaw orthopedics followed by fixed appliances in Class II patients treated at the peak in mandibular growth. The discriminant factor for individual responsiveness to therapy consisted of a significant amount of supplementary growth along total mandibular length in treated Class II patients compared to untreated Class II patients.

## MATERIALS AND METHODS

The study was performed on a sample of 51 subjects (24 females, 27 males) with Class II division 1 malocclusion characterized by full Class II molar relationship, excessive overjet, and ANB angle greater than 4 degrees. Treatment protocol consisted of a first phase with a functional appliance immediately followed by a second phase with fixed appliances to refine occlusion. No auxiliary devices for the correction of Class II malocclusion, such as Class II elastics or headgear, were used during the phase with fixed appliances.

The first phase of therapy was accomplished with a twin block in 16 subjects (8 females and 8 males), with a stainless steel crown Herbst in 15 subjects (9 females and 6 males), and with an acrylic splint Herbst in 20 subjects (7 females and 13 males). The three treatment protocols were accomplished by three clinicians who treated patients consecutively. Design and details of treatment regimen for the three functional appliances have been described elsewhere.<sup>1</sup> Previous reports have indicated that the three types of functional appliances produce similar dentoskeletal effects in Class II patients when evaluated after a phase of fixed appliances.<sup>18,19</sup>

Lateral cephalograms were available at the start of



**Figure 1.** Landmarks, distances, and planes used for the cephalometric analysis.

treatment with FJO (T1) and at the completion of fixed appliance therapy (T2). The average age of the sample was 12 years and 3 months  $\pm$  10 months at T1, and 14 years and 5 months  $\pm$  1 year at T2. The average duration of comprehensive Class II treatment was 2 years and 3 months  $\pm$  7 months. All subjects received treatment with the functional appliances at the peak in mandibular growth as appraised by means of the cervical vertebral maturation method<sup>20</sup> (CS 3 at T1).

## Cephalometric Analysis

*Cephalometric measurements at T1.* The following cephalometric parameters were evaluated at the start of treatment with the functional appliances (T1) (Figure 1).

Sagittal skeletal relationships: ANB ( $^{\circ}$ ); maxillomandibular differential (mm, difference between total mandibular length, Co-Gn, and midfacial length, Co-A).

Vertical skeletal relationships: Palatal plane to Frankfort horizontal ( $^{\circ}$ ); mandibular plane to Frankfort horizontal ( $^{\circ}$ ); palatal plane to mandibular plane ( $^{\circ}$ ).

Morphologic and dimensional mandibular measurements: Co-Go-Me $^{\circ}$ ; B-Pg to Go-Me ( $^{\circ}$ ); ratio between Co-Go and S-Co; ratio between Go-Me and S-N.

*Cephalometric measurements at T2.* At the completion of comprehensive Class II treatment (T2), total

mandibular length (Co-Gn) was measured on the lateral cephalograms of all patients (Figure 1).

### Definition of Mandibular Responsiveness to Class II Treatment Including FJO

Individual responsiveness to Class II treatment including a functional appliance was defined on the basis of the T2-T1 increment in total mandibular length (Co-Gn) in the treated subjects during the observation period when compared with untreated subjects with a Class II malocclusion. For this purpose a group of 19 subjects (11 females and 8 males) with untreated Class II division I malocclusion were selected from the University of Michigan Elementary and Secondary School Growth Study<sup>21</sup> and their lateral cephalograms were analyzed at two time periods: T1, average age of 12 years and 2 months  $\pm$  1 year, and T2, average age of 14 years and 5 months  $\pm$  1 year and 3 months, with an average T1-T2 interval of 2 years and 4 months  $\pm$  9 months. Occlusal and skeletal characteristics of the untreated Class II group matched those of the treated group based on the data of cephalometric measurements at T1. All subjects of the untreated group underwent the peak in mandibular growth during the observation period as appraised by means of the cervical vertebral maturation method (CS 3 at T1).

To overcome slight differences in treatment/observation durations among the subjects treated with the three types of functional appliances and the untreated subjects, T2-T1 differences in total mandibular length were biannualized. The average biannual increase in total mandibular length in the untreated Class II sample was  $3.3 \pm 1.5$  mm.

A clinically significant response in terms of supplementary elongation of the mandible in treated subjects was calculated in accordance with the estimated power for the present study. Because of the number of subjects in the treated and untreated samples, the standard deviations for the examined measurement (T2-T1 differences in Co-Gn), and with the desired power of 0.85, the clinically significant difference for total mandibular length between treated and untreated samples was equal to 2.0 mm. Therefore, the clinically significant amount of supplementary elongation of the mandible in treated subjects in 2 years was set at 5.3 mm.

On the basis of this reference growth increment, "good responders" (GR) to Class II treatment including FJO were defined as those treated subjects showing a biannual increase in Co-Gn greater than 5.3 mm. On the contrary, "bad responders" (BR) to Class II treatment including FJO were defined as those treated subjects showing a biannual increase in Co-Gn equal to or smaller than 5.3 mm. GR consisted of 34 sub-

jects, 15 females and 19 males, whereas BR comprised 17 subjects, 9 females and 8 males.

Lateral cephalograms of both treated and untreated samples at T1 and T2 were standardized as to magnification factor (8%) and analyzed by means of a digitizing tablet (Numonics, Lansdale, Pa) and of digitizing software (Viewbox, ver 3.0, D Halazonetis, Athens, Greece).

### Method Error

The assessment of the method error for the cephalometric measurements was performed on 20 cephalograms selected randomly from the total of the observations using Dahlberg's formula<sup>22</sup>. The error ranged between 0.1 and 0.3 for cephalometric ratios, between 0.1 and 0.8 mm for the linear measurements, and between  $0.2^\circ$  and  $1.2^\circ$  for the angular measurements.

### Data Analysis

Discriminant analysis was applied to cephalometric values of the 51 subjects at T1. In order to arrive at the best model for discrimination, the first phase of the analysis was to select the most important variables for group separation between GR and BR. Therefore, stepwise variable selection was used to identify predictive variables. Forward selection procedure with F-to-enter and F-to-remove equal to 4 was chosen. When the smallest set of significant discriminant variables was selected, the predictive power (classification power) of the model was tested by means of discriminant analysis (SPSS for Windows, version 12, SPSS Inc, Chicago, Ill).

### RESULTS

Stepwise variable selection generated a one-variable model that produced the most efficient separation between the two groups (GR vs BR). The variable selected was the mandibular angle (Co-Go-Me). The classification power of the selected variable model was 80.4 %. Only one out of five cases in each group was not classified correctly. Unstandardized discriminant function coefficients of the selected variable together with a calculated constant lead to the following equation that provides individual scores for the assignment of a new case to GR or to BR:

$$\text{Individual score} = 0.275_{(\text{Co-Go-Me})} - 34.279$$

The critical score (ie, the value dividing GR from BR) is 0.249, ie, the mean value of the group centroids of the two groups (0.498 and 0.996 for GR and BR, respectively). Each new patient with Class II malocclusion at CS 3 that will show an individual score smaller

than the critical score is expected to respond favorably to treatment including FJO in terms of supplementary mandibular elongation. On the contrary, each new patient with Class II malocclusion at CS 3 that will show an individual score greater than the critical score is expected to have a poor response to treatment including FJO in terms of supplementary mandibular elongation. The classification power of the selected model was cross-validated successfully on a separate group of 20 subjects with Class II subjects treated with the same protocols (twin block or Herbst followed by fixed appliances) at CS 3 (classification power = 90%).

From a practical point of view, the single-variable outcome of discriminant analysis enables the direct determination of actual values of the discriminant pretreatment parameter (Co-Go-Me<sup>o</sup>) for the critical score (125.5°). This means that each new Class II patient at CS 3 with a pretreatment value for Co-Go-Me smaller than 125.5° is expected to respond favorably to treatment including FJO in terms of supplementary mandibular elongation. On the contrary, each new Class II patient at CS 3 with a pretreatment value for Co-Go-Me greater than 125.5° is expected to respond poorly to treatment including FJO in terms of supplementary mandibular elongation.

## DISCUSSION

The results of the present study revealed that the Co-Go-Me angle can be used for an efficient discrimination between good and poor responders to treatment of Class II malocclusion with a protocol that includes a first phase with a functional appliance followed immediately by a second phase with fixed appliances to refine occlusion.

The reliability of the mandibular angle as a pretreatment predictor of the outcomes of Class II therapy was cross-validated successfully on a different sample of Class II subjects, thus reinforcing the usefulness of the predictive parameter on newly-observed patients. The prediction error of 20% can be explained easily by taking into consideration the many variables that can influence treatment outcomes in the orthodontic patient regardless of expected average efficacy of a given treatment protocol (patient's compliance, proficiency of the operator, practical management of the appliance, intensity/quality of patient's systemic factors, etc.). It must be stressed that in the present study all subjects started treatment at the peak in mandibular growth.<sup>20</sup>

The clinical and biological meaning of the discriminant pretreatment variable (Co-Go-Me angle) deserves to be elucidated further. After the classical studies by Petrovic et al<sup>9</sup> and Petrovic and Stutzmann,<sup>23</sup> the positive correlation between mandibular growth potential and mandibular responsiveness to

FJO has been clearly established. Petrovic<sup>24</sup> demonstrated that the growth rate, ie, the potential responsiveness of the individual subject to FJO aimed to stimulate growth at the mandibular condyle, is significantly greater in the presence of anterior growth rotation of the mandible than in the presence of posterior growth rotation of the mandible. The morphological mandibular features related to anterior/posterior growth rotation of the mandible are expressed cephalometrically best by the angle formed by the condylar axis and the mandibular base.<sup>9,25</sup>

The results of the present investigation are in agreement with previous experimental findings in both animals and humans,<sup>9</sup> and they suggest that a small pretreatment mandibular angle (Co-Go-Me angle < 125.5°) is correlated with the evidence of an enhanced responsiveness to FJO, and vice versa.

In this conceptual context, it is also important to emphasize differences between cephalometric indicators of mandibular morphology and those of mandibular position within the craniofacial complex. It has been shown in the past that morphological changes of the mandible, namely the change in the inclination of the condyle to the mandibular base, are linked intimately with the growth features of the mandible at the pubertal peak.<sup>26</sup> Moreover, the modification in condylar growth direction is one of the significant skeletal effects of FJO when performed at puberty.<sup>10,11</sup>

The position of the mandible in relation to other craniofacial structures (eg, relation of the mandibular plane to the palatal plane or to the Frankfort plane) does not play a significant role in predicting either mandibular growth direction<sup>25</sup> or individual responsiveness to functional jaw orthopedics.<sup>13,15</sup> In the present study, pretreatment cephalometric variables related to the position of the mandible in the vertical plane did not enter into the discriminant equation between good and poor responders to Class II treatment with FJO. Also, neither the position of the mandible in the sagittal plane nor the amount of skeletal discrepancy between the maxilla and the mandible were significant predictors of individual responsiveness to Class II treatment, in contrast with previous results by Caldwell and Cook<sup>15</sup> and by Patel and coworkers.<sup>17</sup> The comparison with the preexisting literature, however, is hindered by the fact that the present study used supplementary growth of the mandible instead of dentoskeletal correction as a discriminant factor for differential responsiveness to Class II treatment.

## CONCLUSIONS

- Each new Class II patient at the peak in skeletal maturation (CS 3) with a pretreatment value for Co-



Go-Me° smaller than 125.5° is expected to respond favorably to treatment including FJO.

- Each new Class II patient at CS 3 with a pretreatment value for Co-Go-Me° greater than 125.5° is expected to respond poorly to treatment including FJO.
- Vertical and sagittal craniofacial features before treatment are not able to improve this prediction based upon mandibular morphology.

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## REFERENCES

1. McNamara JA, Jr, Brudon WL. *Orthodontics and Dentofacial Orthopedics*. Ann Arbor, Mich: Needham Press; 2001: 67–80.
2. Kelly JE, Harvey C. *An assessment of the teeth of youths 12–17 years*. DHEW Publication No. (HRA) 77-1644. Washington, DC: National Center for Health Statistics; 1977.
3. McLain JB, Proffit WR. Oral health status in the United States: prevalence of malocclusion. *J Dent Educ*. 1985;49: 386–396.
4. Proffit WR, Fields HW, Moray LJ. Prevalence of malocclusion and orthodontic treatment need in the United States: estimates from the N-HANES III survey. *Int J Adult Orthod Orthogn Surg*. 1998;13:97–106.
5. Chen J.Y., Will L.A., Niederman R. Analysis of efficacy of functional appliances on mandibular growth. *Am J Orthod Dentofacial Orthop*. 2002;122:470–476.
6. Cozza P, Baccetti T, Franchi L, De Toffol L, McNamara JA, Jr. Mandibular changes produced by functional appliances in Class II malocclusion: a systematic review. *Am J Orthod Dentofacial Orthop*. In press.
7. Hägg U, Pancherz H. Dentofacial orthopaedics in relation to chronological age, growth period and skeletal development. An analysis of 72 male patients with Class II division 1 malocclusion treated with the Herbst appliance. *Eur J Orthod*. 1988;10:169–176.
8. Malmgren O, Ömblus J, Hägg U, Pancherz H. Treatment with an appliance system in relation to treatment intensity and growth periods. *Am J Orthod Dentofacial Orthop*. 1987; 91:143–151.
9. Petrovic A, Stutzmann J, Lavergne J. Mechanism of craniofacial growth and modus operandi of functional appliances: a cell-level and cybernetic approach to orthodontic decision making. In: Carlson DS, ed. *Craniofacial Growth Theory and Orthodontic Treatment*. Ann Arbor, Mich: Center for Human Growth and Development, The University of Michigan; 1990:13–74. Craniofacial Growth Monograph Series; Monograph 23.
10. Baccetti T, Franchi L, Toth LR, McNamara JA Jr. Treatment timing for Twin-Block therapy. *Am J Orthod Dentofacial Orthop*. 2000;118:159–70.
11. Faltin K Jr, Faltin RM, Baccetti T, Franchi L, Ghiozzi B, McNamara JA Jr. Long-term effectiveness and treatment timing for bionator therapy. *Angle Orthod*. 2003;73:221–230.
12. Ahlgren J, Laurin C. Late results of activator treatment: a cephalometric study. *Br J Orthod*. 1976;3:181–187.
13. Pancherz H. The mandibular plane angle in activator treatment. *Angle Orthod*. 1979;49:11–20.
14. Charron C. Recherche d'éléments pronostiques quant à l'efficacité de l'Activateur en occlusion de classe II d'Angle. *Orthod Fr*. 1989;60:685–693.
15. Caldwell S, Cook P. Predicting the outcome of twin block functional appliance treatment: a prospective study. *Eur J Orthod*. 1999;21:533–9.
16. Ahn SJ, Kim JT, Nahm DS. Cephalometric markers to consider in the treatment of Class II Division 1 malocclusion with the bionator. *Am J Orthod Dentofacial Orthop*. 2001; 119:578–586.
17. Patel HP, Moseley HC, Noar JH. Cephalometric determinants of successful functional appliance therapy. *Angle Orthod*. 2002;72:410–417.
18. Burkhardt DR, McNamara JA Jr, Baccetti T. Maxillary molar distalization or mandibular enhancement: a cephalometric comparison of comprehensive orthodontic treatment including the pendulum and the Herbst appliances. *Am J Orthod Dentofacial Orthop*. 2003;123:108–116.
19. Schaefer AT, McNamara JA Jr, Franchi L, Baccetti T. A cephalometric comparison of treatment with the Twin-block and stainless steel crown Herbst appliances followed by fixed appliance therapy. *Am J Orthod Dentofacial Orthop*. 2004;126:7–15.
20. Baccetti T, Franchi L, McNamara JA Jr. The cervical vertebral maturation (CVM) method for the assessment of optimal treatment timing in dentofacial orthopedics. *Semin Orthod*. 2005;11:119–29.
21. Riolo ML, Moyers RE, McNamara JA Jr, Hunter WS. *An atlas of craniofacial growth: cephalometric standards from the University School Growth Study*, Ann Arbor, Mich: Center for Human Growth and Development, University of Michigan; 1974. Craniofacial Growth Series, Monograph 2.
22. Dahlberg G. *Statistical Methods for Medical and Biological Students*. New York, NY: Interscience Publications; 1940.
23. Petrovic AG, Stutzmann JJ. The concept of mandibular tissue-level growth potential and the responsiveness to a functional appliance. In: Graber WL, ed. *Orthodontics: State of the Art, Essence of the Science*. St. Louis, Mo: CV Mosby Co; 1986:59–74.
24. Petrovic AG. A cybernetic approach to craniofacial growth control mechanisms. *Nova Acta Leopold*. 1986;58:27–67.
25. Ødegaard J. Mandibular rotation studied with the aid of metal implants. *Am J Orthod*. 1970;58:448–454.
26. Franchi L, Baccetti T, McNamara JA Jr. Thin-plate spline analysis of mandibular growth. *Angle Orthod*. 1981;71:83–89.