Growth modulation using functional appliances—Cephalometric predictors of successful response

Sharanya Ajit Kumar, BDS, MDS¹
K. Sadashiva Shetty, BDS²
A.T. Prakash, BDS, MOth RCSEd³

Aim: The aim of this study was to determine any skeletal morphologic features evident on a pretreatment lateral cephalogram that may be used to predict improvement in the sagittal relationship during functional appliance therapy in Class II patients and compare changes between cases with and without a favorable response to growth modulation. Method: Pretreatment and postfunctional lateral cephalograms were analyzed, and the change in the ANB angle was used to determine the skeletal response to treatment with a functional appliance. Based on the change in the ANB angle, the patients were divided into two groups of 12 patients each. Comparisons were made between the mean pretreatment (T1) cephalometric parameters of group I (skeletal) and group II (nonskeletal) to assess any pretreatment parameters that were significantly different between the groups. Changes due to functional appliance therapy from the pretreatment (T1) to postfunctional (T2) stage was measured as T2-T1 in both groups. The mean changes seen in group I and group II were then compared to assess the difference between changes brought about by growth modulation using functional appliances. Comparative statistical analysis of the data was done using one-way analysis of variance F test. Results and conclusion: This study showed that not all cases respond favorably to growth modulation. The pretreatment parameters that correlated to a favorable response were low mandibular plane angle, low basal plane angle, and a high Jarabak ratio. In those cases that responded favorably, the changes seen were an increase in Co-Go (ramus height), decrease in overjet, increase in SNB, and increase in the Jarabak ratio. ORTHODONTICS (CHIC) 2013;14:e50–e59. doi: 10.11607/ortho.917

Key words: growth modulation, growth pattern, prediction of growth, case selection, functional appliance, success prediction

Historically, the field of orthodontics has been concerned with the correction of malocclusion, primarily by means of controlled movement of the developing and mature dentition into a desirable occlusal relationship. Control and modification of growth of the skeletal structures of the craniofacial complex, especially via tooth-borne appliances, has also been a prominent but controversial area of interest and activity within the field of orthodontics since its inception.

¹Senior Lecturer, Department of Orthodontics and Dentofacial Orthopedics, Vydehi Institute of Dental Sciences & Research Centre, Bangalore, Karnataka, India.
²Professor and Head, Department of Orthodontics and Dentofacial Orthopedics; Principal, Bapuji Dental College & Hospital, Davangere, Karnataka, India.
³Reader, Department of Orthodontics and Dentofacial Orthopedics, Bapuji Dental College & Hospital, Davangere, Karnataka, India.

CORRESPONDENCE
Dr Sharanya Ajit Kumar
Department of Orthodontics and Dentofacial Orthopedics
Vydehi Institute of Dental Sciences & Research Centre
#82, E.P.I.P Area, Nallurahalli, Whitefield, Bangalore 560066,
Karnataka, India
Email: drsharanyaortho@gmail.com

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Growth modulation carried out using functional appliances has been a topic of much debate. The key factors in its success probably are correct diagnosis, case selection, appliance design, and patient cooperation. According to Bishara and Ziaja, the term functional appliance refers to a variety of orthodontic appliances designed to alter the activity of various muscle groups that influence the function and position of the mandible in order to transmit forces to the dentition and the basal bone. Altering the sagittal and vertical mandibular position generates these changes in muscular forces and results in orthopedic and orthodontic changes. One of the original functional appliances, the monobloc, was designed by Robin in 1902, and various functional appliances have been used extensively since the 1930s. Despite this relatively long history, there continues to be much controversy relating to their use, method of action, and effectiveness.

Selecting cases to ensure a successful response to functional appliance therapy remains a challenge because the treatment results are often variable and unpredictable. There is a wide individual variation in the response to treatment even when broadly similar malocclusions are treated. Studies have shown varying degrees of success in the treatment outcomes; hence, functional appliance use remains controversial. A treatment outcome that has been particularly questioned is the enhancement of mandibular growth. Differing responses to treatment may be due to the design of the appliances. It is also possible that different functional appliance designs act in dissimilar ways and are not directly comparable. The variations in appliance design, amount of mandibular advancement, types of construction bite, and prescribed time of wear are so marked that practically no two investigators use similar parameters.

It is generally accepted that the prognosis of Class II malocclusion treatment is partially dependent on the mandibular plane angle. Pancherz demonstrated that low angle cases having a favorable horizontal growth pattern are easier to treat and retain than high angle cases with a vertical growth pattern. Individual differences in sensory and neuromuscular response to functional appliance therapy could also be responsible for variations in treatment outcome. Assuming that a patient is compliant and wearing the appliance as instructed, it may be that pretreatment skeletal morphologic factors are responsible for a favorable or unfavorable treatment outcome. Categorizing cases according to the response to treatment provides an opportunity to compare characteristics and identify differences between those that responded with a skeletal change and those that did not. This may help us to decide which cases will respond to growth modulation and which will not and hence provide us with a useful clinical tool. Therefore, the objectives of this study were to determine any cephalometric parameters evident on a pretreatment cephalogram that can be used to predict a successful response to growth modulation using functional appliances and also to compare the changes observed after growth modulation between those cases that responded well to growth modulation and those that did not.

METHODS

Source of data
Twenty-four growing patients (13 female and 11 male) with a Class II skeletal pattern treated with functional appliance therapy in the Department of Orthodontics and Dentofacial Orthopedics, Bapuji Dental College and Hospital, Davangere, Karnataka, India, were selected for the study. Two sets of lateral cephalograms (pretreatment and postfunctional) were used for the study. The mean age of patients was 10 years at the beginning of treatment and 13 years at end of treatment.
Criteria for selection of data

- Class II skeletal bases.
- Growing patients treated with functional appliance to advance the mandible: twin block or Fränkel appliance for a minimum duration of 1 year. All patients were compliant.
- No previous orthodontic treatment undertaken. No headgear used.

Method of data collection

Pretreatment and postfunctional lateral cephalograms were analyzed, and the change in the ANB angle was used to determine the skeletal response to treatment with a functional appliance. Based on the change in the ANB angle, the patients were divided into two groups of 12 patients each:

- Group I: 12 patients who demonstrated a change in ANB angle of 4 degrees or more; identified as the skeletal group.
- Group II: 12 patients who demonstrated a change in ANB angle of 1 degree or less; identified as the nonskeletal group.

Patients who demonstrated a moderate change in ANB angle, between 1 and 4 degrees, were omitted.

Lateral cephalograms were taken in occlusion under standardized conditions with a cephalostat. Tracings were made on 0.003-inch acetate paper with a 0.3-mm lead pencil, and the landmarks were identified. All tracings were checked to verify the accuracy. Measurements were manually made on pretreatment (T1) and postfunctional (T2) lateral cephalograms for both groups.
Reference lines or planes used were (Fig 1):

1. True vertical line (TVL): plane through sella at 97 degrees to the sella-nasion plane
2. Basion-nasion plane: plane constructed from basion to nasion
3. Maxillary plane (MxP): plane constructed from ANS to PNS
4. Mandibular plane (MnP): plane constructed from menton to gonion
5. Corpus axis: line from Xi point to Pm

Measurements included the following parameters:

Linear parameters (mm):
1. S-N: linear measurement from sella to nasion
2. S-Ar: linear measurement from sella to articulare
3. Upper anterior facial height (UAFH): N to ANS measured parallel to TVL
4. Lower anterior facial height (LAFH): ANS to gnathion measured parallel to TVL
5. Co-Go: linear distance between condylion and gonion; determines length of mandibular ramus
6. Co-Gn: linear distance between condylion and gnathion; determines overall length of mandible
7. Go-Gn: linear distance between gonion and gnathion; determines length of mandibular body
8. Overbite: degree of vertical overlap of mandibular central incisors by their maxillary antagonists, measured perpendicular to the occlusal plane
9. Overjet: degree of horizontal overlap of mandibular central incisors by their maxillary antagonists, measured parallel to the occlusal plane

Angular parameters (degrees):
10. N-S-Ar: saddle angle; angle between SN plane and S-Ar plane; angle between the anterior and posterior cranial base
11. S-Ar-Go: articular angle; angle between S-Ar and Ar-Go planes
12. SNA: angle formed by the intersection of SN plane to a line joining nasion and point A; determines the anteroposterior position of the maxilla to the cranial base
13. SNB: angle formed by the intersection of SN plane to a line joining nasion and point B; determines the anteroposterior position of the mandible to the cranial base
14. ANB: angle formed between the lines NA and NB; relates to the anteroposterior position of the mandible to the maxilla
15. SN-MxP: determines the inclination of the maxillary plane to the SN plane (anterior cranial base)
16. SN-MnP: determines the inclination of the mandibular plane to the SN plane (anterior cranial base)
17. Basal plane angle (MxP-MnP): determines inclination of the mandibular plane to the maxillary plane
18. Mandibular arc: angle formed by intersection of condylar axis and a backward extension of corpus axis; mean measurement: 26 ± 4 degrees
19. Maxillary incisor–MxP: determines inclination of the long axis of the most protrusive maxillary incisor to the maxillary plane
20. Mandibular incisor–MnP: determines inclination of the long axis of the most protrusive mandibular incisor to the mandibular plane

Percentage parameter:
21. Jarabak ratio: posterior facial height (S-Go) multiplied by 100 and divided by the anterior facial height (N-Me).
Descriptive data that included mean and standard deviation values were calculated for the linear, angular, and percentage parameters. Comparative statistical analysis of the data between both groups was done using one-way analysis of variance $F$ test. A $P$ value $< .05$ was set for statistical significance.

The following analyses were performed:

- Comparisons were made between the mean pretreatment (T1) parameters of Group I and Group II to assess any pretreatment parameters that were significantly different between the groups that may help in predicting the response to growth modulation.
- Changes due to functional appliance therapy from pretreatment (T1) to post-functional (T2) stage was measured as T2-T1 in both groups. The mean changes seen in groups I and II were then compared to assess the difference in changes brought about by growth modulation using functional appliances.

Ethical committee review in this study was deemed unnecessary for the following reasons:

- The study was retrospective in nature, and all the cases were treated with written consent.
- There were no untreated control groups.

### Table 1 Comparative data for the pretreatment (T1) cephalometric measurements

<table>
<thead>
<tr>
<th>Variable</th>
<th>Group 1</th>
<th>Group 2</th>
<th>$F$ value</th>
<th>$P$ value</th>
</tr>
</thead>
<tbody>
<tr>
<td>S-N (mm)</td>
<td>69.30</td>
<td>68.60</td>
<td>0.25</td>
<td>.65</td>
</tr>
<tr>
<td>S-Ar (mm)</td>
<td>34.10</td>
<td>33.10</td>
<td>0.76</td>
<td>.39</td>
</tr>
<tr>
<td>UAFH (mm)</td>
<td>48.30</td>
<td>49.50</td>
<td>0.88</td>
<td>.36</td>
</tr>
<tr>
<td>LAFH (mm)</td>
<td>51.80</td>
<td>53.90</td>
<td>1.04</td>
<td>.32</td>
</tr>
<tr>
<td>Co-Go (mm)</td>
<td>49.80</td>
<td>48.80</td>
<td>0.38</td>
<td>.54</td>
</tr>
<tr>
<td>Co-Gn (mm)</td>
<td>101.00</td>
<td>101.40</td>
<td>0.03</td>
<td>.88</td>
</tr>
<tr>
<td>Go-Gn (mm)</td>
<td>67.40</td>
<td>68.20</td>
<td>0.20</td>
<td>.7</td>
</tr>
<tr>
<td>Overbite (mm)</td>
<td>3.60</td>
<td>3.30</td>
<td>0.19</td>
<td>.67</td>
</tr>
<tr>
<td>Overjet (mm)</td>
<td>10.10</td>
<td>8.30</td>
<td>0.15</td>
<td>.99</td>
</tr>
<tr>
<td>N-S-Ar (degrees)</td>
<td>126.00</td>
<td>125.30</td>
<td>0.38</td>
<td>.54</td>
</tr>
<tr>
<td>S-Ar-Go (degrees)</td>
<td>142.20</td>
<td>146.60</td>
<td>0.21</td>
<td>.09</td>
</tr>
<tr>
<td>SNA (degrees)</td>
<td>80.30</td>
<td>79.80</td>
<td>0.1</td>
<td>.76</td>
</tr>
<tr>
<td>SNB (degrees)</td>
<td>73.70</td>
<td>73.70</td>
<td>0.0</td>
<td>1</td>
</tr>
<tr>
<td>ANB (degrees)</td>
<td>6.60</td>
<td>6.20</td>
<td>0.57</td>
<td>.46</td>
</tr>
<tr>
<td>SN-MxP (degrees)</td>
<td>8.10</td>
<td>9.80</td>
<td>1.94</td>
<td>.18</td>
</tr>
<tr>
<td>SN-MnP (degrees)</td>
<td>30.00</td>
<td>34.40</td>
<td>8.28</td>
<td>.05*</td>
</tr>
<tr>
<td>MxP-MnP (degrees)</td>
<td>21.90</td>
<td>25.30</td>
<td>5.76</td>
<td>.05*</td>
</tr>
<tr>
<td>Mandibular arc (degrees)</td>
<td>31.70</td>
<td>31.10</td>
<td>0.12</td>
<td>.74</td>
</tr>
<tr>
<td>UI-MxP (degrees)</td>
<td>55.80</td>
<td>60.80</td>
<td>3.35</td>
<td>.08</td>
</tr>
<tr>
<td>LI-MnP (degrees)</td>
<td>104.80</td>
<td>100.30</td>
<td>4.07</td>
<td>.06</td>
</tr>
<tr>
<td>Jarabak ratio (%)</td>
<td>67.20</td>
<td>63.90</td>
<td>5.75</td>
<td>.05*</td>
</tr>
</tbody>
</table>

UI = upper (maxillary) incisor; LI = lower (mandibular) incisor.
*Statistically significant difference.
RESULTS

The descriptive statistics of all the linear, angular, and percentage variables measured are presented in Tables 1 and 2. Table 1 presents comparative data for the pretreatment cephalometric measurements at the start of treatment (T1) for the two groups. Comparisons were made between the mean pretreatment (T1) parameters of groups I and II to assess any pretreatment parameters that were significantly different between the groups that may help in predicting the response to growth modulation. Changes due to functional appliance therapy from pretreatment (T1) to postfunctional (T2) stage was measured as T2-T1 in both groups. The mean changes seen in groups I and II were then compared (see Table 2) to assess the difference between changes brought about by growth modulation using functional appliances.

The pretreatment values that were significantly different between the groups were the mandibular plane angle (SN-MnP), basal plane angle (MxP-MnP), and Jarabak ratio (Fig 2). The mean value of SN-MnP in the skeletal group was 30 ± 3.9 degrees and in the nonskeletal group was 34.4 ± 3.6 degrees. The mean value of the basal plane angle in the skeletal group was 21.9 ± 4.4 degrees and in the nonskeletal group was 25.3 ± 2.3 degrees. The mean value of the Jarabak ratio in the skeletal group was 67.2% ± 3.7% and in the nonskeletal group was 63.9% ± 3.0%.

### Table 2  Comparison of changes observed from pretreatment (T1) to postfunctional (T2) stage (T2 – T1)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Group 1</th>
<th></th>
<th>Group 2</th>
<th></th>
<th>F value</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SD</td>
<td>Mean</td>
<td>SD</td>
<td></td>
<td></td>
</tr>
<tr>
<td>S-N (mm)</td>
<td>1.7</td>
<td>1.7</td>
<td>1.3</td>
<td>1.0</td>
<td>0.53</td>
<td>.47</td>
</tr>
<tr>
<td>S-Ar (mm)</td>
<td>1.7</td>
<td>1.6</td>
<td>1.0</td>
<td>1.8</td>
<td>0.97</td>
<td>.34</td>
</tr>
<tr>
<td>UAFH (mm)</td>
<td>1.8</td>
<td>1.5</td>
<td>2.0</td>
<td>1.5</td>
<td>0.16</td>
<td>.69</td>
</tr>
<tr>
<td>LAFH (mm)</td>
<td>5.1</td>
<td>3.5</td>
<td>4.3</td>
<td>2.0</td>
<td>0.52</td>
<td>.48</td>
</tr>
<tr>
<td>Co-Go (mm)</td>
<td>4.5</td>
<td>3.3</td>
<td>1.9</td>
<td>1.8</td>
<td>5.8</td>
<td>&lt;.05*</td>
</tr>
<tr>
<td>Co-Gn (mm)</td>
<td>6.4</td>
<td>4.8</td>
<td>4.8</td>
<td>2.6</td>
<td>1.01</td>
<td>.33</td>
</tr>
<tr>
<td>Go-Gn (mm)</td>
<td>3.2</td>
<td>2.4</td>
<td>2.8</td>
<td>2.1</td>
<td>0.13</td>
<td>.72</td>
</tr>
<tr>
<td>Overbite (mm)</td>
<td>-1.1</td>
<td>2.1</td>
<td>-0.7</td>
<td>2.0</td>
<td>0.25</td>
<td>.62</td>
</tr>
<tr>
<td>Overjet (mm)</td>
<td>-6.5</td>
<td>2.8</td>
<td>-3.7</td>
<td>2.5</td>
<td>6.64</td>
<td>&lt;.05*</td>
</tr>
<tr>
<td>N-S-Ar (degrees)</td>
<td>-0.9</td>
<td>1.9</td>
<td>-0.2</td>
<td>2.0</td>
<td>0.88</td>
<td>0.36</td>
</tr>
<tr>
<td>S-Ar-Go (degrees)</td>
<td>1.2</td>
<td>5.6</td>
<td>-1.1</td>
<td>2.4</td>
<td>1.64</td>
<td>0.21</td>
</tr>
<tr>
<td>SNA (degrees)</td>
<td>-0.3</td>
<td>1.8</td>
<td>0.4</td>
<td>1.0</td>
<td>1.63</td>
<td>0.22</td>
</tr>
<tr>
<td>SNB (degrees)</td>
<td>3.8</td>
<td>1.9</td>
<td>1.0</td>
<td>0.9</td>
<td>23.2</td>
<td>&lt;.001†</td>
</tr>
<tr>
<td>ANB (degrees)</td>
<td>-4.2</td>
<td>0.4</td>
<td>-0.6</td>
<td>0.5</td>
<td>369.8</td>
<td>&lt;.001†</td>
</tr>
<tr>
<td>SN-MxP (degrees)</td>
<td>-0.6</td>
<td>2.7</td>
<td>-0.6</td>
<td>2.1</td>
<td>0.0</td>
<td>1</td>
</tr>
<tr>
<td>SN-MnP (degrees)</td>
<td>-1.2</td>
<td>3.5</td>
<td>0.3</td>
<td>2.3</td>
<td>1.34</td>
<td>.26</td>
</tr>
<tr>
<td>MxP-MnP (degrees)</td>
<td>-0.6</td>
<td>2.1</td>
<td>0.2</td>
<td>3.3</td>
<td>0.45</td>
<td>.51</td>
</tr>
<tr>
<td>Mandibular arc (degrees)</td>
<td>0.4</td>
<td>3.6</td>
<td>0.0</td>
<td>4.2</td>
<td>0.07</td>
<td>.8</td>
</tr>
<tr>
<td>UI-MxP (degrees)</td>
<td>8.3</td>
<td>7.9</td>
<td>4.9</td>
<td>5.6</td>
<td>1.42</td>
<td>.25</td>
</tr>
<tr>
<td>LI-MnP (degrees)</td>
<td>3.8</td>
<td>5.8</td>
<td>0.3</td>
<td>3.4</td>
<td>3.08</td>
<td>.09</td>
</tr>
<tr>
<td>Jarabak ratio (%)</td>
<td>2.6</td>
<td>2.2</td>
<td>0.3</td>
<td>1.5</td>
<td>8.94</td>
<td>&lt;.01†</td>
</tr>
</tbody>
</table>

*Significant difference.
†Highly significant difference.
Also, there was a statistically significant difference in the change brought about by functional appliance therapy between the groups in Co-Go (ramus height), overjet, SNB, and Jarabak ratio (Figs 3 and 4). The mean value of the change in Co-Go in the skeletal group was $4.5 \pm 3.3$ mm and in the nonskeletal group was $1.9 \pm 1.8$ mm. The mean value of the change in overjet in the skeletal group was $-6.5 \pm 2.8$ mm and in the nonskeletal group was $-3.7 \pm 2.5$ mm. The mean value of the change in SNB in the skeletal group was $3.8 \pm 1.9$ degrees and in the nonskeletal group was $1.0 \pm 0.9$ degrees. The mean value of the change in the Jarabak ratio in the skeletal group was $2.6\% \pm 2.2\%$ and in the nonskeletal group was $0.3\% \pm 1.5\%$. 

Fig 2 Comparison between groups I and II at pretreatment stage for given parameters.

Fig 3 Comparison between the changes seen in groups I and II after functional appliance treatment for given linear parameters.

Fig 4 Comparison between the changes seen in groups I and II after functional appliance treatment for given angular parameters.
DISCUSSION

In 1960, Ricketts said that prior to the development of the x-ray and cephalostat, the orthodontist was prone to take full credit for all the growth changes that occurred during treatment. All favorable changes were thought to be due to the beneficial changes induced by the appliance, and poor results were often passed off as a result of poor cooperation.

Even though it seems to be widely accepted that functional appliances stimulate mandibular growth, does scientific investigation justify this acceptance? Creekmore and Radney, in an attempt to answer this question, found that in Class II cases the horizontal component of growth or movement of the condyle was greater for those patients who were treated with a Fränkel appliance as compared with those treated only with edgewise treatment, for whom it was in turn significantly greater compared with the untreated Class II sample.

However, the literature contains conflicting reports with regard to how exactly growth modulation works. Some authors have shown a profound skeletal response to treatment, while others like Wieslander and Lagerström have proved that the changes are mostly dentoalveolar and that the mandible cannot grow any more than it would have otherwise. Therefore, this study has aimed to determine if any skeletal morphologic features evident on a pretreatment lateral cephalogram may be used to predict a successful improvement in the sagittal skeletal base relationship during growth modulation with functional appliance therapy in patients with a Class II skeletal pattern.

There was no significant difference in either S-N or S-Ar values between the two groups at the pretreatment stage, and neither parameter was influenced differently by treatment between the groups. The same was true for the saddle angle (N-S-Ar). This is probably because functional appliance therapy with either the Fränkel or twin block appliance had a negligible influence on the cranial base structures.

Comparison of ramus height (Co-Go) between the two groups at the pretreatment stage revealed no significant difference. Thus, the cases all had a short ramus at the start of treatment. However, as a result of treatment, the Co-Go in the skeletal group increased a mean of 4.5 mm, while in the nonskeletal group the mean increase was only 1.9 mm. This difference was statistically significant. Thus it can be interpreted that in successful cases the ramus growth in the vertical direction contributes to correction. Comparison of the overall length of the mandible (Co-Gn) between the groups at the pretreatment stage and also the difference in the change in the Co-Gn following treatment was not found to be statistically significant between the groups. A possible interpretation could be that the mandible length increased in both groups, but in the nonskeletal group this did not contribute to decreasing the ANB to a significant extent since the direction of growth was more downward than forward.

The comparison of the overbite values between the groups at the pretreatment stage and also the difference in the change in the overbite by treatment was not found to be statistically significant between the groups. At the beginning of treatment both groups had a deep bite tendency, which was reduced as a result of treatment. Tulley stated that functional appliances worked to the best advantage in those cases in which there was a deep overbite rather than those in which there was a very flat occlusal plane.

It is commonly believed that a large saddle angle implies a posteriorly positioned glenoid fossa and a posterior condylar position. According to Graber et al, this must be compensated by angular (S-Ar-Go) and linear (ramal height) relationships. Uncompensated posterior positioning of the mandible caused by a large saddle angle is very difficult to treat. In this study there were no significant differences seen in the change in articular angle between the groups.
However, a slight decrease in the articular angle was seen in the nonskeletal group, which could suggest that since the ramus height had not compensated well the articular angle attempted to correct the Class II condition. Although the difference was not statistically significant, it could be clinically significant.

The comparison of the SNB values between the groups at the pretreatment stage was not found to be statistically significant. For those who responded skeletally, there is a much greater forward movement of B point. This was in agreement to the findings by Patel et al7 and in disagreement with the study by Rushforth and Gordon,13 who found that the majority of the correction when using the Fränkel appliance came from dental movements, the most significant being the retroclination of the maxillary incisor teeth and proclination of the mandibular teeth, while forward mandibular growth was not a significant factor.

The difference in the ANB values between the groups at the pretreatment stage was not found to be statistically significant. Hence the severity of Class II in both groups was the same pretreatment. This helped to eliminate any selection bias in the study. In a previous study14 by Ahlgren and Laurin, it was found that the pretreatment ANB value was the only morphologic difference between successfully and unsuccessfully treated cases, with the successfully treated group having a larger ANB angle before treatment than the unsuccessfully treated group. The mean value of the change in ANB between the groups was found to be highly statistically significant, indicating a profound improvement in the sagittal relation between the jaws in the skeletal group.

The comparison of the SN-MnP values between the groups at the pretreatment stage showed that the mean value of SN-MnP was 30 degrees in the skeletal group and 34.4 degrees in the nonskeletal group. The difference was statistically significant. This was in agreement with studies by Pancherz5 and Franchi and Baccetti.15 They believed that the prognosis of treating Class II malocclusions is partly dependent on the mandibular plane angle. Low angle cases, having a favorable horizontal growth pattern, are easier to treat and retain than high angle cases with a vertical growth pattern, but this was in disagreement with the study by Patel et al,7 who found no difference in the SN-MnP angle between the groups at the start of treatment. In the nonskeletal group of this study, there was a slight increase in the mandibular plane angle, indicating a backward rotation of the mandible as a result of treatment in this group. Since the comparisons were made between the changes seen between two groups, the values were only mildly different and did not prove to be statistically significant.

The mean pretreatment value of the basal plane angle (MxP-MnP) was found to be 21.9 degrees in the skeletal group and 25.3 degrees in the nonskeletal group. The difference was statistically significant. This also goes to prove that the skeletal group at the pretreatment stage had more converging jaw bases, which reflect a more horizontal growth direction. After treatment, the difference in the changes seen in the basal plane angle between the groups was not statistically significant.

Although the differences were not statistically significant, in the skeletal group the maxillary and mandibular incisors were more proclined at the pretreatment stage, and as a result of treatment the maxillary incisors were more retroclined and the mandibular incisors were more proclined compared with the nonskeletal group. Thus, dentoalveolar changes also contributed to the correction, more so in the skeletal group than in the nonskeletal group. In the nonskeletal group, the lack of sufficient dental compensation seen in the form of maxillary incisor retroclination and mandibular incisor proclination could be one of the reasons why the overjet did not decrease as much as it did in the skeletal group.

The mean pretreatment value of the Jarabak ratio was found to be 67.2% in the skeletal group and 63.9% in the nonskeletal group. The difference was statistically significant, showing that at the pretreatment stage the skeletal group
had an increased posterior to anterior facial height ratio, indicating a more horizontal growth pattern compared with the nonskeletal group. The mean value of the change in the Jarabak ratio was found to be 2.6% in the skeletal group and 0.3% in the nonskeletal group. The difference was statistically significant, implying that in the skeletal group a significant increase in the posterior facial height was achieved compared with in the nonskeletal group. This supports the finding of an increase in the ramal height seen in the skeletal group.

CONCLUSION

Selecting the right cases for growth modulation has been a topic of much debate. This study concludes that not all cases respond favorably to growth modulation using functional appliance therapy. The pretreatment parameters that related to a favorable response were low mandibular plane angle, low basal plane angle, and a high Jarabak ratio. Also, in those cases that responded favorably, the changes seen were an increase in Co-Go, decrease in overjet, increase in SNB, and increase in the Jarabak ratio. The opposite was true in cases that did not respond favorably. The significance of these results will only have clinical application if patients with high growth potential can be identified at the start of treatment.

The limitations of the study are that the sample size of the experimental group was 12 patients in each group. There was no uniform distribution between the male and female patients. Therefore, sex-based comparisons could not be carried out. Lateral cephalograms were used, which are two-dimensional representations of three-dimensional objects. A more accurate representation could be obtained from three-dimensional data using computed tomography images. In the future, a prospective study could be planned with a higher sample size that is categorized uniformly based on sex. Increasing the sample size could facilitate more substantial results. An index could be prepared for case selection for growth modulation.

REFERENCES