Cephalometric evaluation of dento-skeletal changes during treatment with the Bionator Type 1

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SUMMARY Treatment effects of the Bionator functional appliance were studied on the pre- and post-treatment cephalograms of 49 Class II, Division 1 cases. After treatment, a significant more ventral localization of the anterior structures of the mandible was recorded in comparison with the pre-treatment situation. The proclination of the maxillary incisors was reduced. No absolute inhibitory effect on maxillary growth was observed. In this study no significant differences in the measured treatment effects on cephalometric radiographs could be demonstrated in cases with a tendency to skeletal open bite from those with a tendency to skeletal deep bite according to the criteria used in this study.

Introduction

Functional treatment has its roots in Western Europe (Andræsen, 1936; Andresen et al., 1953; Eschler, 1952; Herren, 1959; Balters, 1964; Bimler, 1964; Fränkel, 1969; Stockfisch, 1971), where it has served for many years as an accepted approach for the correction of particularly Class II, Division 1 malocclusions, before it gained geographically wider acceptance (Schulhof & Engel, 1982; Gianelli et al., 1983; Righelli, 1983; McNamara, 1985). The results obtained from the many studies of treated cases differ considerably, as do the opinions expressed on the effect of treatment with functional appliances, and on their mode of action (Carels & van der Linden, 1987).

A distinct effect on the position and inclination of the teeth was shown about in most studies (orthodontic effects). Several investigators concluded that treatment effects are limited to the dento-alveolar area (Björk, 1951; Harvold & Vargervik, 1971; Janson, 1977; Creekmore & Radney, 1983; Robertson, 1983) and that the correction of the distal occlusion with functional treatment could partly be ascribed to an increase in the mandibular alveolar height in the molar region (Harvold & Vargervik, 1971; Ahlgren & Laurin, 1976).

It has been shown that functional treatment can have a restricting influence on the growth of the maxilla (Ahlgren & Laurin, 1976; Bookstein, 1982; Baumrind et al., 1983a). In a comparative investigation of several facial orthopaedic treatment approaches, it was found that in an activator-treated group, the distal displacement of the maxillary molars had about equal orthodontic and orthopaedic contributions (Baumrind et al., 1983a). A study in which untreated Class II cases served as controls, showed that functional treatment has the effect of compressing the facial polygon in the anteroposterior direction and enlarging it in the vertical direction (Bookstein, 1982).

Different opinions have also been expressed concerning the effect of functional treatment on the growth of the mandible. Some investigators assumed that condylar growth is not influenced by treatment (Björk, 1951; Jakobsson, 1967; Harvold & Vargervik, 1971). Others concluded that the growth of the mandible is the distinguishing aspect of functional treatment with respect to other therapeutic procedures (Reey & Eastwood, 1978; Owen, 1981).
Class II, Division 1 malocclusions are those most suited for functional treatment. However, it has been argued (Teuscher, 1978) that the underlying skeletal pattern has to be taken into account in deciding whether the application of functional therapy is justified. After identifying 15 subgroups in Class II anomalies, Moyers et al. (1980) and Moyers et al. (1976) postulated that patients of the same facial type not only look alike, but also grow alike, have similar treatment needs and probably respond to the same treatment in a similar fashion.

The various skeletal types are brought about by different skeletal growth patterns. Facial skeletal growth largely contributes to the development of occlusal relationships (Marschner & Harris, 1966; Björk, 1969; van der Linden, 1986). Björk (1969) demonstrated that the positioning, and repositioning, of the mandibular dentition relative to the maxillary dentition and the skull during growth and during treatment, depends chiefly on the mandibular growth rotation. According to van der Linden (1986), the growth pattern of the dentofacial complex is mainly determined by the intra- and extra-oral functional components.

Several authors stressed the effect of functional therapy on craniofacial growth (Björk, 1951; Ricketts, 1960; Jakobsson, 1967; Williams & Melsen, 1982a,b; Fränkel & Fränkel, 1983; Nielsen, 1984). As to the growth direction expressed at the chin, an increase of the X-axis has been recorded (Brechtold et al., 1981), while an average decrease of the facial axis was found in another study (Reey & Eastwood, 1978). However, it also has been stated that the mandible continues its normal growth pattern and thus is not affected by the functional treatment (Ulgen, 1981).

Cases with vertical hyperdevelopment of the lower third of the face, have frequently been considered as reacting unfavourably to the application of functional therapy since it would stimulate further the vertical development of the face. However, it can be questioned whether certain types of functional therapy that have a specific training effect on the orofacial and masticatory musculature would redirect the facial growth pattern. From this point of view, it could be argued that the resulting vertical dimensions of the face might not exceed those from the undisturbed growth. An argument in favour of this hypothesis is provided by Fränkel & Fränkel (1983), who showed a decrease of the mandibular plane angle and only moderate increases of the lower face height in skeletal open bite cases treated with the Functional regulator. An answer to the question whether certain types of functional therapy would redirect the facial growth pattern is relevant for the indication of functional treatment in subjects with a divergent skeletal pattern.

The purpose of this investigation was: first to study the influence of Bionator treatment on the dentofacial complex in a Class II, Division 1 sample including subjects with various skeletal patterns, and secondly, to evaluate whether there is a differential influence of Bionator treatment on some selected dentofacial characteristics in subjects with a ‘skeletal deep bite’ compared to those with a ‘skeletal open bite’.

Materials and methods

A cephalometric study was performed on pre- and post-treatment standardized lateral headplates available from 49 Class II, Division 1 cases (23 boys and 26 girls) successfully treated with the Bionator in the late mixed or early permanent dentition. The mean age of the subjects at the start of treatment was 11 years and 5 months (s.d. = 1 year, 5 months). The average treatment duration was 1 year and 7 months (s.d. = 9 months). Before treatment, all children presented a Class II, Division 1 malocclusion with various degrees of severity and various degrees of crowding. The first maxillary premolars were extracted in three cases and the second in two cases.

All children had been treated by the second author with the Bionator type 1 appliance, according to the concepts of Balters (1964). The bionators were constructed as illustrated in Fig. 1 a & b. The construction bite for the appliances was taken with the incisors in edge-to-edge position and with the mandibular in an overcorrected neutral- or even mesio-occlusion. Initially, the occlusal surfaces of the posterior teeth in both jaws were completely covered with acrylic. After 1–3 months, the acrylic was removed from the occlusal surfaces of the mandibular first molars and, near the end of the treatment, also at the mandibular premolars sites. This resulted in a selective eruption of teeth, contributing to the sagittal and vertical correction of the Class II, Division 1 malocclusions.

All exposures for the cephalograms were taken by one operator in the same headholder. The distance between the focus and the median plane of the head was fixed at 4 m and the film was put as close as possible to the subjects head.
Fig. 1. (a & b) The Bionator type 1 appliance used in all the subjects; (c & d) the mandible is positioned in incisal edge-to-edge relation when the appliance is in the mouth.
Cephalometric landmarks and tracings were digitized (Fig. 2) and the values for 22 angular and linear variables (Table 1), were calculated by the computer.*

A univariate statistical analysis† of the variables in the pre- and post-treatment samples was performed. The distribution appeared to be normal and therefore a paired t-test was used to quantify differences between pre- and post-treatment measurements and between the pre- and post-treatment measurements to the norms for age with this group. (Table 1.)

To investigate the possible differential responses to Bionator treatment in subjects with varying types of craniofacial skeletal morphology (Fig. 3), a discriminant analysis was performed to evaluate whether there are differences between each time two subgroups characterized by percentile criteria of 10 different cephalometric variables. The upper and lower quartiles of the distribution curve, of 10 variables, served as selection criteria for the composition of each of the subgroups. The number of cases included in the subgroups and the criteria for selection, are given in Table 2.

**Results**

The pre- and post-treatment data were compared to the norms matched for age and sex with our patients. The results of this comparison are displayed in Table 1. The data with the average values standard deviations and the P-values of the differences between pre- and post Bionator treatment of the whole sample are presented in Table 2.

In this sample, Bionator treatment resulted in a significant absolute reduction of the maxillary incisor proclination (var 16 : ISN). In accordance, the interincisal angle (var 22 : 1 i) increased considerably. The maxillary length (var 14: CoA) as well as the mandibular length (var 17: CoGn) increased significantly. The anterior part of the mandible was in a more ventral position (var 18: SNB), while the sagittal position of the maxilla (var 15: SNA) did not change significantly. The facial plane (var 19: NPo FH) showed a small but significant increase; the conicity (var 20:MP NPo) decreased.

The angular lower facial height (var 10: ANS Xi Pm) increased significantly, as did the linear lower facial height (var 11: ANS Me). The posterior and anterior facial heights (var 13: S Go and var 12: NMe) both became significantly larger and in about the same proportions (respectively 9 and 8%).

No significant differences were shown for the other variables, including the mandibular plane angle to the anterior cranial base (var 1: SN MP), the mandibular plane to the Frankfort plane (var 3: PP MP and var 4: OP MP), the saddle angle (var 5: N S Ar), the articular angle (var. 6: S Ar Go), the gonial angle (var. 7: Ar Go Me), the modified Y-axis (var 8: NS Gn) and the facial axis (var 9: Ba CC Gn).

A discriminant analysis was used to evaluate the differences between each of 10 subgroups. The 10 variables used as criteria for composing the subgroups are characteristic for each time two types of skeletal patterns. Each first subgroup included cases showing a tendency for a skeletal deep bite, hypodivergence of the skeletal bases (var 2: FMPA), a low anterior to posterior facial height (var 12: NMe/var 13: S IGo) or a low anterior lower facial height (var 7: Ar Go Me, var 10: ANS Xi Pm). Each second subgroup included cases showing a tendency for a skeletal open bite with the opposite characteristics. The results of the discriminant analysis were negative for each of the created subgroups according to the selected criteria. The changes associated with the treatment did not differ significantly between the subgroups for any of the selected criteria.
Table 1 Changes in the cephalometric variables in 49 Class II, Division 1 cases before and after treatment with the Bionator. The level of significance of the difference calculated by means of the paired t-test, is indicated by *** (P < 0.001), ** (P < 0.01) and * (P < 0.05). The abbreviations of the variables are described in the Results section.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Before mean</th>
<th>Before s.d.</th>
<th>After mean</th>
<th>After s.d.</th>
<th>Significance level of the difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. SN MP</td>
<td>33.2°</td>
<td>4.7</td>
<td>32.8°</td>
<td>5.5</td>
<td>/</td>
</tr>
<tr>
<td>2. FMPA</td>
<td>25.2°</td>
<td>4.7</td>
<td>25.7°</td>
<td>5.3</td>
<td>/</td>
</tr>
<tr>
<td>3. PP MP</td>
<td>26.3°</td>
<td>4.8</td>
<td>26.1°</td>
<td>6.0</td>
<td>/</td>
</tr>
<tr>
<td>4. OP MP</td>
<td>15.2°</td>
<td>4.6</td>
<td>14.9°</td>
<td>4.3</td>
<td>/</td>
</tr>
<tr>
<td>5. NS Ar</td>
<td>125.6°</td>
<td>5.2</td>
<td>124.8°</td>
<td>5.5</td>
<td>/</td>
</tr>
<tr>
<td>6. S Ar Go</td>
<td>142.6°</td>
<td>6.4</td>
<td>143.6°</td>
<td>6.4</td>
<td>/</td>
</tr>
<tr>
<td>7. Ar Go Me</td>
<td>125.0°</td>
<td>5.6</td>
<td>124.7°</td>
<td>6.6</td>
<td>/</td>
</tr>
<tr>
<td>8. NS GN</td>
<td>68.8°</td>
<td>3.1</td>
<td>68.8°</td>
<td>3.7</td>
<td>/</td>
</tr>
<tr>
<td>9. Ba CC Gn</td>
<td>89.5°</td>
<td>3.5</td>
<td>89.1°</td>
<td>3.7</td>
<td>/</td>
</tr>
<tr>
<td>10. ANS Xi PM</td>
<td>43.5°</td>
<td>4.8</td>
<td>44.9°</td>
<td>4.8</td>
<td>***</td>
</tr>
<tr>
<td>11. ANS Me</td>
<td>57.9 mm</td>
<td>4.6</td>
<td>63.2 mm</td>
<td>4.9</td>
<td>***</td>
</tr>
<tr>
<td>12. NMe</td>
<td>107.4 mm</td>
<td>6.8</td>
<td>115.4 mm</td>
<td>8.0</td>
<td>***</td>
</tr>
<tr>
<td>13. S Go</td>
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<td>5.7</td>
<td>78.6°</td>
<td>7.0</td>
<td>***</td>
</tr>
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<td>14. CoA</td>
<td>83.5°</td>
<td>4.9</td>
<td>87.0°</td>
<td>5.4</td>
<td>***</td>
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<td>15. SNA</td>
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<td>3.6</td>
<td>82.4°</td>
<td>3.8</td>
<td>/</td>
</tr>
<tr>
<td>16. ISN</td>
<td>106.2 mm</td>
<td>9.5</td>
<td>97.1°</td>
<td>8.3</td>
<td>***</td>
</tr>
<tr>
<td>17. CoGn</td>
<td>101.4°</td>
<td>6.3</td>
<td>108.9°</td>
<td>7.0</td>
<td>***</td>
</tr>
<tr>
<td>18. SNB</td>
<td>75.5°</td>
<td>3.5</td>
<td>76.9°</td>
<td>3.6</td>
<td>**</td>
</tr>
<tr>
<td>19. NPo FH</td>
<td>84.9°</td>
<td>3.2</td>
<td>85.6°</td>
<td>3.5</td>
<td>*</td>
</tr>
<tr>
<td>20. MP NPo</td>
<td>70.1°</td>
<td>4.1</td>
<td>69.3°</td>
<td>4.5</td>
<td>**</td>
</tr>
<tr>
<td>21. i MP</td>
<td>94.2°</td>
<td>8.3</td>
<td>95.9°</td>
<td>8.1</td>
<td>*</td>
</tr>
<tr>
<td>22. II</td>
<td>125.9°</td>
<td>12.6</td>
<td>132.7°</td>
<td>11.2</td>
<td>***</td>
</tr>
</tbody>
</table>

Discussion

As was found in other studies on the effects of functional appliances treatment (Harvold & Vargervik, 1971; Janson, 1977; Wieslander & Lagerstrom, 1979; Creekmore & Radney, 1983; Robertson, 1983; Pancherz, 1984; Bolmgren & Moshiri, 1986), our data show that in growing children, Bionator treatment brings about a number of significant changes relative to the pre-treatment situation. These significant changes include the reduction of the proclination of the maxillary incisors, the increase of the angular lower face height (var. 10: ANSX:PM), the increase of the linear anterior lower face height (var. 11: ANS Me), the increase in total anterior face height (var. 12: NMe), the increase in posterior total face height (var. 13: SGo), the increase in linear measurement representing the maxillary length (var. 14: CoA), the increase of the length of the mandible (var. 17: CoGn) the more anterior position of the mandible relative to the skull base and relative to other skeletally based reference lines of the skull (var. 18: SNB; var. 19: NPo-FH and var. 20: MPNPo). It is known from several longitudinal studies of non-treated children that during the undisturbed (untreated) growth of the face some similar cephalometric changes could occur to various degrees (e.g. Moyers et al., 1976). The only changes that could not possibly be attributed to growth alone, are the observed dento-alveolar changes.

Our data did not reveal an absolute more posterior position of the maxilla (var. 15: SNA). Also the maxillary length has increased significantly in absolute terms. In the sagittal direction, maxillary growth does not seem to be inhibited absolutely by the Bionator therapy. This could be explained by the absence of any contact with maxillary incisors (in contrast, for example, with the activator and with the headgear-activator). Clinically, this could imply that, if an absolute inhibition of the maxillary forward growth is desired, a functional appliance with a frontal dental overcapping, combined with a headgear is indeed preferable (Bass, 1982; Van Beek, 1982).

It also could be argued however, that point A was advanced by dento-alveolar changes at the incisor
region, since a palatal tipping of the maxillary incisor crowns was accompanied by the ventral displacement of their apices. This could mask a possible restraining effect on maxillary growth. In the same light, the observed increase in maxillary length (CoA) can be attributed to anterior displacement of point A. The same comments apply to the SNA measurement.

Although the recorded increase in mandibular length is significant, no conclusion can be drawn, as is also the case for the other variables, concerning the possibility of stimulating mandibular growth by means of the Bionator therapy, since no control group of untreated Class II cases was available for comparison. The significant increases of SNB, MP NPo and NPo FH indicate that on average the anterior part of the mandible is more anteriorly positioned after a combination of normal growth and functional treatment. This is in accordance with the results of Baumrind et al. (1983b) and in agreement with the Bionator treatment effects observed after a short period of treatment which constitute a forward mandibular positioning (Carels & van Steenberghe, 1986). However, the consideration that they have to be compared with changes occurring in non-treated Class II children, in order to separate treatment effects from growth changes also applies to these results.

The findings of the present study do not indicate that the overall morphology of the dentofacial complex is significantly altered by Bionator treatment. Indeed, the ventral displacement of the anterior part of the mandible was accompanied by vertical changes. However, the facial axis and the F-axis did not change significantly, and Bionator treatment was not associated with a noticeable posterior rotation of the mandible on the average; both the anterior and the posterior part of the lower face height increased in about the same proportion.

Our observations are in agreement with the recordings from Ulgen (1981), who also did not find an

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**Table 2** Discriminating variables and selection criteria for partitioning the sample into each time consecutively two subgroups

<table>
<thead>
<tr>
<th>Discriminating variable</th>
<th>Group I Value</th>
<th>n</th>
<th>Group II Value</th>
<th>n</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. FMPA</td>
<td>22-5°</td>
<td>11</td>
<td>28-0°</td>
<td>13</td>
</tr>
<tr>
<td>2. PP MP</td>
<td>22-5°</td>
<td>11</td>
<td>29-8°</td>
<td>12</td>
</tr>
<tr>
<td>3. NS Ar</td>
<td>123-3°</td>
<td>12</td>
<td>129-0°</td>
<td>12</td>
</tr>
<tr>
<td>4. AT GO Me</td>
<td>121-3°</td>
<td>12</td>
<td>129-8°</td>
<td>10</td>
</tr>
<tr>
<td>5. NS Gn</td>
<td>66-5°</td>
<td>15</td>
<td>71-5°</td>
<td>14</td>
</tr>
<tr>
<td>6. Ba CC Gn</td>
<td>92-0°</td>
<td>14</td>
<td>87-0°</td>
<td>11</td>
</tr>
<tr>
<td>7. ANS XI Pm</td>
<td>40-0°</td>
<td>11</td>
<td>47-0°</td>
<td>14</td>
</tr>
<tr>
<td>8. ANS Me</td>
<td>54-5 mm</td>
<td>10</td>
<td>60-9 mm</td>
<td>10</td>
</tr>
<tr>
<td>9. NMe</td>
<td>101-7 mm</td>
<td>10</td>
<td>111-9 mm</td>
<td>12</td>
</tr>
<tr>
<td>10. S Go</td>
<td>68-1 mm</td>
<td>10</td>
<td>76-5 mm</td>
<td>12</td>
</tr>
</tbody>
</table>
influence on the overall morphology of the mandible using the headgear activator. Reey & Eastwood (1978) using the passive activator found an average decrease of the facial axis of 1.0° whilst an average increase of the Y-axis of 0.1° was also recorded by Brechtold et al. (1981). During facial growth, the facial axis remains relatively stable (McNamara, Bookstein & Shaughnessy, 1985a). Compensatory remodelling of the lower border of the mandible could, however, be of importance in this respect.

Since treatment responses did not significantly differ between the two subgroups, a more optimistic attitude should be advocated toward the treatment with the Bionator of Class II Division 1 anomalies with tendency to skeletal open bite. In our sample, the average bite raising effect of functional appliances in subjects with tendency for skeletal open bite was not significantly different from that in subjects with a tendency for skeletal deep bite. This finding is in contrast with the generally accepted idea regarding the influence of the forces exerted by the jaw muscles. Subjects with a tendency to skeletal deep bite are thought to exhibit less vertical development during therapy than those with a tendency to skeletal open bite. The reason that this difference in bite raising effect between the two skeletal types does not show up in our study, might lay in the fact that the variability of the skeletal morphology of our patients did not show real extremes. Fränkel & Fränkel (1983) showed that skeletal open bite cases could be corrected towards average skeletal norms by means of the functional regulator. They attributed the underlying anteriorly directed mandibular skeletal growth pattern, to changes in the orofacial musculature induced by the functional appliance.

To provide definitive evidence that skeletal open bite tendencies are no contra-indication for the application of Bionator therapy, probably more extreme cases should be included in future investigations.

Finally, future studies should also include data on patients which are out of therapy for a number of years, as clinical observations reveal that distinct changes still take place after the treatment is completed. In that respect it would therefore be interesting to reobserve the patients of the present sample 5, 10 and 15 years out of retention, to evaluate which changes remained stable over the long-term and to find out in which cases unfavourable craniofacial developments occurred afterwards.

**Conclusion**

It can be concluded that during the treatment with the Bionator maxillary incisors become more upright, that no absolute dorsal effect has been observed on the maxilla and that no significant differential effect can be observed between patients with tendency to open or deep bite skeletal patterns.

**References**


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