Original Article

Effective Condylar Growth and Chin Position Changes in Activator Treatment: A Cephalometric Roentgenographic Study

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Abstract: Effective condylar growth (a summation of condylar remodeling, glenoid fossa remodeling, and condylar position changes within the fossa) and its influence on the position of the chin was analyzed in 40 class II, division I malocclusions treated successfully with activators. Additionally, the amount of mandibular rotation was assessed. Lateral head films in habitual occlusion from before and after an average treatment period of 2.6 years were evaluated. The Bolton Standards (32 untreated individuals with ideal occlusion) served as controls. Two different treatment effects were evaluated: overall growth change and treatment effects (overall growth changes minus age-related Bolton values). In comparison with the Bolton group, the activator patients exhibited an increase in the amount of vertical effective condylar growth (3.0 mm; $P < .001$), a decrease in the amount of sagittal effective condylar growth (0.6 mm; $P < .05$), and an increase in the amount of vertical development of the chin (1.8 mm; $P < .001$). No group differences could be found for sagittal development of the chin. In the Bolton group, the mandible rotated posteriorly, and in the activator group it rotated anteriorly (2.7°; $P < .001$). The present investigation revealed that effective condylar growth can be increased and the chin position can be changed by activator treatment. Thus activator treatment induces skeletal changes, although not always in the desired (sagittal) therapeutic direction. (*Angle Orthod* 2001;71:4–11.)

Key Words: Condylar growth; Chin position changes; Skeletal treatment effects; Class II treatment; Activator; Cephalometric roentgenography; Orthodontics; Dentofacial orthopedics

INTRODUCTION

The general objectives in dentofacial orthopedics of skeletal class II malocclusions that use the activator[1] are to normalize the occlusion and to improve the patient's facial profile by increasing mandibular prognathism. Most authors agree on the influence of the activator upon the dentoalveolar area.[2–14] The orthopedic effect of the appliance, however, is a controversial topic of discussion. Some authors state that the skeletal effect of activator therapy is confined to a restriction of maxillary growth,[2,6,7,9,15,16] whereas others are of the opinion that the activator stimulates condylar, and thus mandibular, growth.[17–24] An influence of activator treatment on the glenoid fossa has also been reported.[17,25]

In a recent overview article by Aelbers and Dermaut[26] comparing different functional appliances, the authors reported that 86% of the activator studies available in literature show a significant reduction of the ANB angle during treatment. They concluded, however, that the ANB changes achieved by activator therapy are biologically insignificant. The ANB reduction noted during activator treatment might be within the range of what would have occurred without treatment,[3] and this implies that mandibular growth is not stimulated to a clinically significant extent[27] by activator therapy.

One of the main pitfalls of a cephalometric evaluation analyzing condyle and fossa changes during orthodontic treatment is the reference landmark. The reproducibility of the location of condylion on mouth-closed lateral head films is limited.[28–30] Articulare, on the other hand, can be located with an acceptable reproducibility,[13,31] but it is influenced by growth and can thus be unreliable in the assessment of longitudinal growth changes.[32] Furthermore, activator therapy has been said to cause a backward rotation of the mandible,[14,33,34] which would mask a possible in-

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crease in mandibular length when using anterior mandibular reference points such as the B-point or the pogonion (Pg) point. These methodological problems might account for some of the controversy on skeletal treatment effects of functional appliances.

For the evaluation of mandibular growth, the method of Creekmore[35] and others[36–38] measures the effective condylar growth, which is a summation of the changes resulting from condylar remodeling, glenoid fossa remodeling, and positional changes of the condyle within the fossa. Thus, 3 adaptive processes in the temporomandibular joint contributing to the changes in mandibular position are assessed. The advantage of this approach is that it overcomes the above-mentioned methodological problems by using an arbitrary condylar point. Furthermore, a possible mandibular rotation during treatment does not influence the measured effective condylar growth changes, as is the case for other reference points (such as the B-point or the Pg-point[29,36,39]) frequently used in the assessment of mandibular growth changes.

Since it remains unclear whether the activator is able to alter the mandibular growth pattern or causes only dentoalveolar changes, the present study is aimed at clarifying whether the activator has a skeletal treatment effect on the mandible. This will be done by assessing the effective condylar growth and its influence on the position of the chin in the treatment of class II malocclusions.

MATERIALS AND METHODS

Subjects

The patient material comprised 40 (17 boys and 23 girls) Class II, division I malocclusions randomly selected from the total group of successfully treated Andresen-Activator patients.[1] The mean pretreatment age of the patients was 10.4 ± 1.3 years. Lateral head films with the teeth in habitual occlusion from before and after an average treatment period of 2.6 (1.2–3.4) years were available.

The Bolton Standards[40] were used as a control sample. These standards are composed of longitudinal growth data and annual composite lateral head film tracings from 32 untreated subjects (16 boys and 16 girls) with ideal occlusion who were followed from 1 year to 18 years of age. For the comparison with the activator subjects, the acetate templates of the Bolton Standards were used, and the Bolton data were interpolated to suit the individual age and examination interval of each activator patient.

Method

The lateral head films of the activator patients and the templates of the Bolton sample were evaluated. A linear roentgenographic enlargement of 7% in the activator subjects was not corrected. The enlargement of the Bolton tracings varied between 5.5% and 5.8% and was adapted to

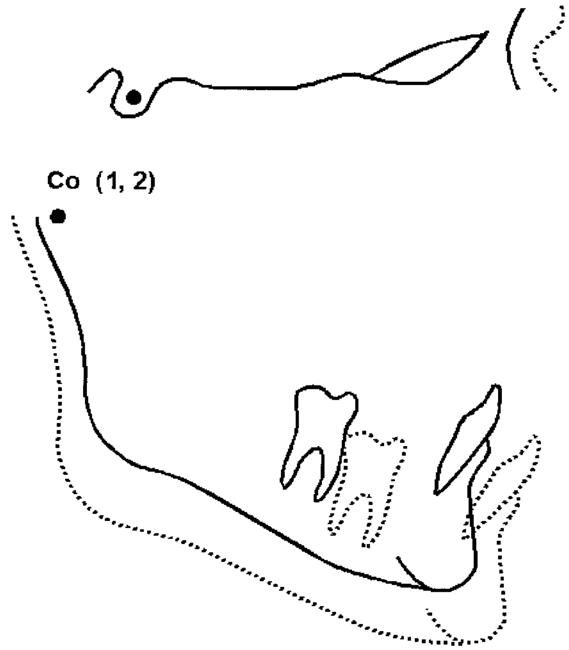

FIGURE 1. Definition of the condylar point. An arbitrary point in the area of the condylar head is marked on the first head film (1) and then transferred to the second head film (2) after superimposition of the films on the stable anterior cranial base bone structures.

that of the activator patients. Linear and angular measurements were performed to the nearest 0.5 mm and 0.5 degrees, respectively. All registrations were done twice, and the mean value of the duplicate registrations was used in the final evaluation.

To assess the effective condylar growth (the summation of condylar remodeling, fossa remodeling, and condylar position changes within the fossa), the chin position changes and the rotational changes of the mandible, the patient roentgenograms and the Bolton tracings in a series were superimposed on the first film or tracing, respectively. Anterior cranial base and mandibular superimpositions were performed according to the method of Björk and Skieller[41] using stable bone structures and the lower border of the mineralized second or third molar germ (before root development begins) for orientation.

Landmarks

Two reference points were used in the evaluation of the patient head films and the Bolton tracings: the condylar point (Co) and the Pg point. The condylar point was an arbitrary point in the area of the condylar head.[35–38] The point was defined on the head film from before treatment and transferred to the film after treatment, after superimposition of the films on the stable bone structures of the anterior cranial base[41] (Figure 1). The Pg point was the most anterior point of the bony chin. The point was defined separately on the head films from before and after treatment.

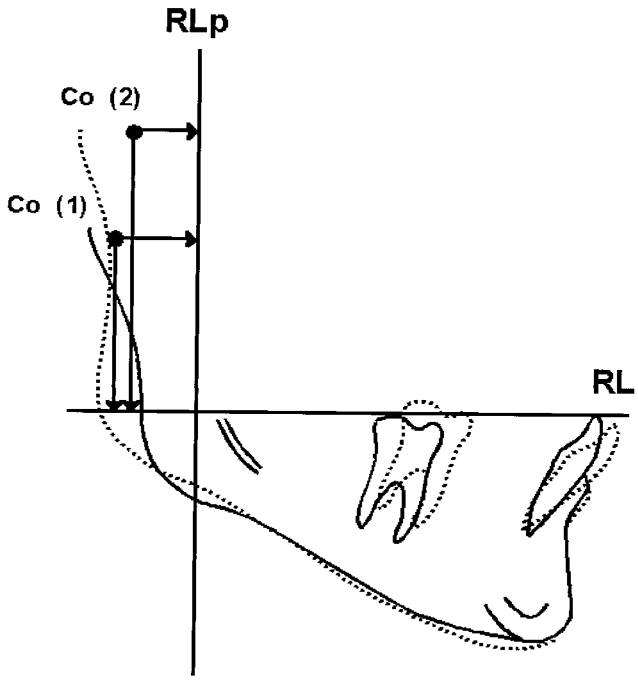

FIGURE 2. Measurements of effective condylar growth (condylar-point changes) in relation to the reference grid made of a reference line and reference line perpendicular (defined on the first head film). Superimposition of the second head film (2) on the first head film (1) using the stable mandibular bone structures for orientation.

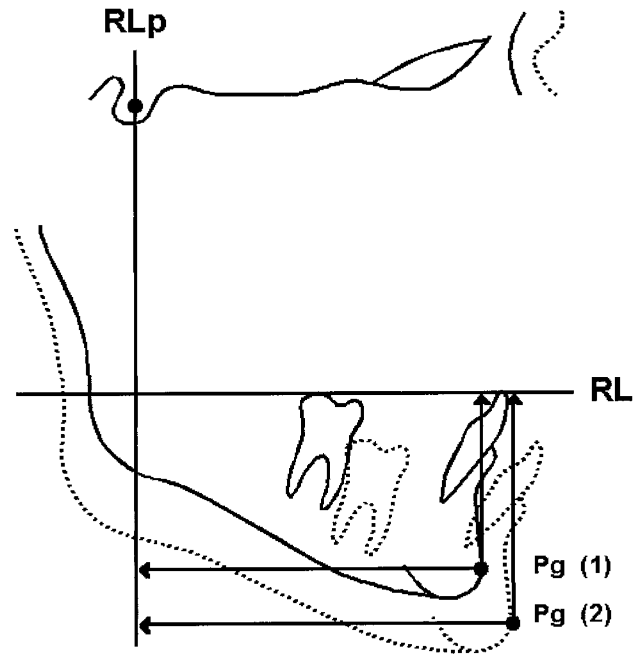

FIGURE 3. Measurements of chin position changes in relation to the reference line/reference line perpendicular reference grid (defined on the first head film). Superimposition of the second head film (2) on the first head film (1) using the stable anterior cranial base bone structures for orientation.

Reference grid

A reference grid made of a reference line (RL) and reference line perpendicular (RLp) was defined on the before-treatment head film and transferred to the posttreatment head film after superimposition of the films on the stable bone structures of the anterior cranial base.[41] The RL line was a line that connects the incisal edge of the most prominent central lower incisor and the distobuccal cusp tip of the first permanent lower molar. The line corresponds to the x-axis of the grid. The RLp was a line perpendicular to RL through the midpoint of the sella turcica. The line corresponds to the y-axis of the grid.

Variables and measuring procedure

The treatment changes of the reference points (Co and Pg) were related to the reference grid (RL/RLp). The sagittal (x) and vertical (y) coordinates of Co and Pg were assessed. The before-treatment values represented the 0-point in the grid.

In measuring the changes of the reference points and reference line, the following procedure was used. For the Co point, superimposition of the head films was done on the stable bone structures of the mandible[41] (Figure 2). The position change of the Co point is equivalent to the effective condylar growth and is a summation of condylar remodeling, glenoid fossa remodeling, and condylar position changes in the fossa. The distance changes Co/RLp imply sagittal effective condylar growth, and the distance changes Co/RL imply vertical effective condylar growth.

For the Pg, superimposition of the head films was done on the stable bone structures of the anterior cranial base[41] (Figure 3). The position change of the Pg point is equivalent to the change in chin position and is the result of effective condylar growth and rotation of the mandible. The distance changes Pg/RLp imply sagittal chin position changes, and the distance changes Pg/RL imply vertical chin position changes.

For the RL, superimposition of the head films was done on the stable bone structures of the mandible[41] (Figure 4). The angular change of the RL line represents the total rotation[41] of the mandible. This is a result of effective condylar growth, vertical maxillary growth, vertical dentoalveolar changes in the maxilla and the mandible, the amount of overbite correction, and the steepness of incisal guidance.

Two different treatment effects were evaluated: overall growth change (physiological growth plus changes induced by the activator) and treatment effect change (overall growth minus age-related Bolton value representing physiological growth changes), corresponding to the true changes accomplished by the activator.

Statistical methods

For each variable, the arithmetic mean and the standard deviation were calculated. To assess gender and group dif-

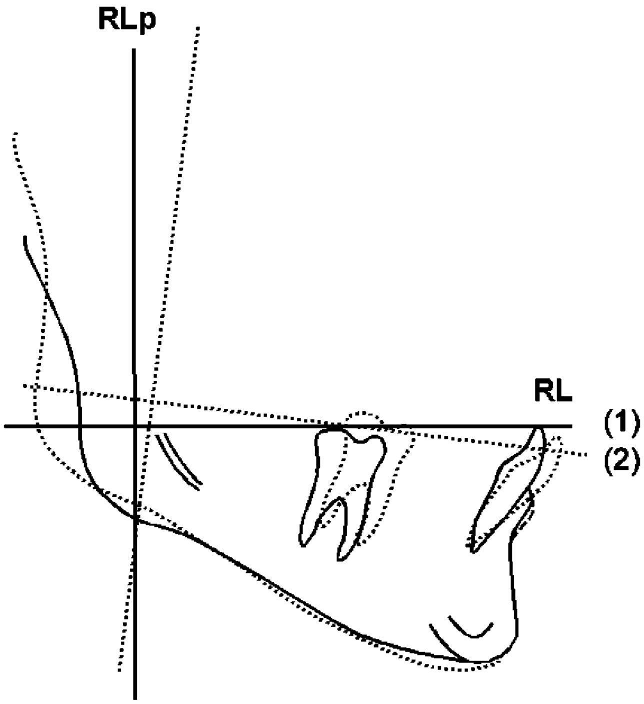

FIGURE 4. Measurements of mandibular rotation. Superimposition of the second head film (2) on the first head film (1) using the stable mandibular bone structures for orientation.

ferences, Student's *t*-test for unpaired samples was utilized. The levels of significance used were $P < .001$, $P < .01$, and $P < .05$; $P \geq .05$ was not considered significant. All calculations were performed with an IBM Personal Computer (Pentium 200) and the software Microsoft (Redmond, Wash) Excel 8.0.

Method error evaluation

The size of the combined method error in locating the reference points, superimposing the roentgenograms, and measuring the variables was assessed upon double registrations of all 40 subjects. The formula of Dahlberg[42] was used in the calculations:

$$\mathrm{ME} = \sqrt{\frac{\sum d^2}{2n}},$$

where d is the difference between 2 registrations of a pair and n is the number of double registrations.

The method error amounted to 0.8 mm for the effective Co and Pg changes and to 0.7° for the rotation of the mandible.

RESULTS

All 40 successfully treated activator patients were treated to a class I dental arch relationship with normal overjet and overbite (Figure 5). The changes of the variables during the examination period are presented in Table 1.

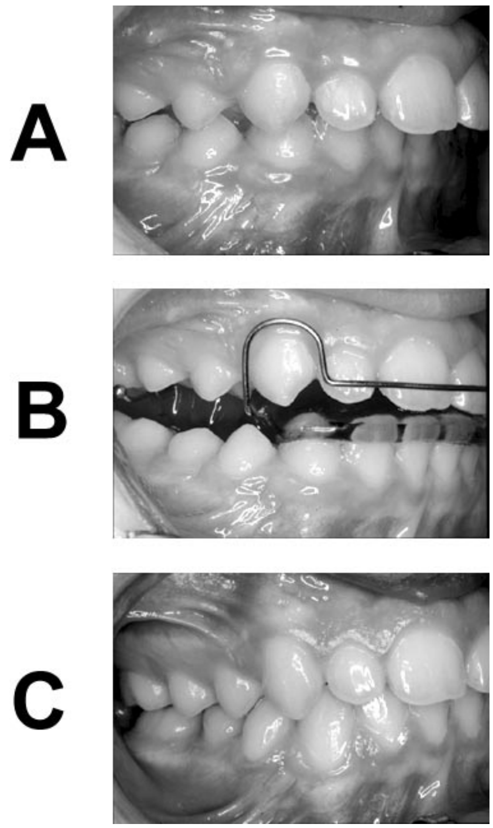

FIGURE 5. Activator treatment in an 11-year-old boy (A) before treatment, (B) activator in place, and (C) after treatment.

Overall growth changes

Effective condylar growth and chin position changes. During the treatment period, the changes of the Co point in the activator group exhibited a large interindividual variation (Figure 6). On average, the Co point changed its position ($P < .001$) almost 5 times more vertically upward (mean = 9.6 mm) than horizontally backward (mean = 2.1 mm). Compared with the Bolton group, the Co change in the activator group was slightly smaller (mean = 0.6 mm; $P < .05$) in the horizontal direction and 1.5 times larger (mean = 3.0 mm; $P < .001$) in the vertical direction.

Similar to the Co point, the Pg point changes in the activator group exhibited a large interindividual variation (Figure 7). On average, the Pg point changed its position 4.3 mm horizontally forward and 6.8 mm vertically downward. In the horizontal direction, the Pg change was about equally large in the activator and Bolton groups (4.3 mm and 4.1 mm, respectively). In the vertical direction, however, the Pg change was more pronounced ($P < .001$) in the activator group than in the Bolton group (6.8 mm and 5.0 mm, respectively).

When comparing the male and female subjects of the activator group, no sex differences were found for any variable, although the changes tended to be more extensive in the male subjects, especially in vertical direction.

TABLE 1. Changes in Cephalometric Variables[a]

Variable[b]	Gender Group	Observation Period (10.3–12.9 y)								
		Activator (Total)			Bolton		Activator/Bolton	Activator (Netto)		
		Mean[c,d]	SD	*P* Value	Mean[c,d]	SD	*P* Value	Mean[c,d]	SD	*P* Value
Co/RLp, mm	B	−2.7	1.57	. . .	. . .	. . .	. . .	0.0	. . .	. . .
	G	−1.7	1.60	. . .	. . .	. . .	. . .	+1.1	. . .	. . .
	B + G	−2.1	1.66	$P < .001$	−2.7	0.86	$P < .05$	+0.6	1.82	$P < .05$
	B/G	−1.0	. . .	ns	. . .	. . .	. . .	−1.1	. . .	ns
Co/RL, mm	B	+10.8	4.08	. . .	. . .	. . .	. . .	+4.3	. . .	. . .
	G	+8.7	2.46	. . .	. . .	. . .	. . .	+2.1	. . .	. . .
	B + G	+9.6	3.40	$P < .001$	+6.6	1.64	$P < .001$	+3.0	3.12	$P < .001$
	B/G	+2.1	. . .	ns	. . .	. . .	. . .	+2.2	. . .	$P < .05$
Pg/RLp, mm	B	+4.7	3.19	. . .	. . .	. . .	. . .	+0.5	. . .	. . .
	G	+4.0	2.70	. . .	. . .	. . .	. . .	0.0	. . .	. . .
	B + G	+4.3	2.94	$P < .001$	+4.1	1.41	ns	+0.2	3.05	ns
	B/G	+0.7	. . .	ns	. . .	. . .	. . .	+0.5	. . .	ns
Pg/RL, mm	B	−7.8	2.46	. . .	. . .	. . .	. . .	−3.0	. . .	. . .
	G	−6.1	2.38	. . .	. . .	. . .	. . .	−0.9	. . .	. . .
	B + G	−6.8	2.57	$P < .001$	−5.0	1.10	$P < .001$	−1.8	2.64	$P < .001$
	B/G	−1.7	. . .	$P < .05$	. . .	. . .	. . .	−2.1	. . .	$P < .05$
RL, degrees	B	−1.7	2.46	. . .	. . .	. . .	. . .	−2.5	. . .	. . .
	G	−1.9	1.79	. . .	. . .	. . .	. . .	−2.8	. . .	. . .
	B + G	−1.8	2.10	$P < .001$	+0.9	0.83	$P < .001$	−2.7	2.27	$P < .001$
	B/G	+0.2	. . .	ns	. . .	. . .	. . .	+0.3	. . .	ns

[a] Changes are in 40 activator patients (17 boys, 23 girls) and in the Bolton Standards during 2.6 years of observation. The overall growth changes (Total) and the treatment effects (Netto) of the activator subjects are given.
[b] Co indicates condylar; RLp, reference line perpendicular; RL, reference line; Pg, pogonion.
[c] − indicates backward movement of Co, downward movement of Pg, and anterior rotations of RL.
[d] + indicates upward movement of Co, forward movement of Co and Pg, and posterior rotation of RL.

Mandibular rotation. The rotation of the RL line in the activator group exhibited a large interindividual variation, with both anterior and posterior rotations being found (Figure 8). On average, the RL line rotated 1.8° ($P < .001$) anteriorly during the 2.6 years of treatment, whereas the line in the Bolton group rotated posteriorly (mean = 0.9°). The group difference was statistically significant ($P < .001$).

When comparing the male and female subjects of the activator group, no sex differences with respect to the direction or to the amount of changes were found.

Treatment effects

Effective condylar growth and chin position changes. The Co point moved vertically upward (mean = 3.0 mm; $P < .001$) and slightly horizontally forward (mean = 0.6 mm; $P < .05$) during the 2.6 years of activator treatment (Figure 9), whereas the Pg point moved mostly vertically downward (mean = 1.8 mm; $P < .01$) and very little horizontally forward (mean = 0.2 mm; $P < .001$).

When comparing the male and female subjects of the activator group, sex differences were found for vertical changes only. The changes of the Co and Pg points were more pronounced in the male subjects ($P < .05$).

Mandibular rotation. The RL line rotated anteriorly (mean = 2.7°; $P < .001$) during the 2.6 years of activator treatment. No sex differences existed.

DISCUSSION

The present control sample was composed of untreated subjects with ideal occlusions (Bolton Standards).[40] To eliminate possible differences in growth pattern, it would have been desirable to compare the data of the activator group with longitudinal growth data of untreated class II malocclusions. Unfortunately, no such sample containing a sufficient number of subjects exists. As the main difference between class I and class II subjects was found to be the absolute size of the mandible rather than the growth pattern,[43–45] it seemed valid to use the Bolton Standards as control group. However, because of the lack of skeletal maturity data for the Bolton Standards, the comparison with the activator group could be performed only on an age-related basis; thus, differences in growth velocity cannot be excluded.[46–48] Furthermore, an earlier onset of the pubertal growth spurt in the activator patients in comparison with the Bolton subjects because of secular reasons cannot be ruled out.[49–51] Therefore, the described group differences may in part be the result of differences in the timing and the pubertal growth rates.

Overall growth changes

The analysis of the overall growth changes in the activator group in comparison with the Bolton Standards group revealed that effective condylar growth could be increased

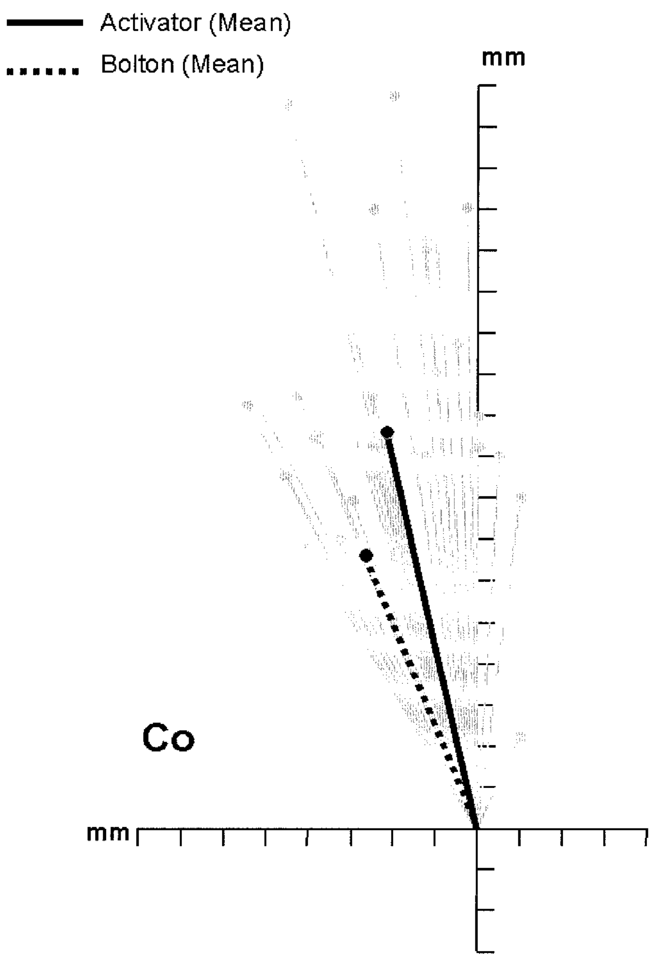

FIGURE 6. Overall growth changes (individual values). Effective condylar growth changes in 40 activator patients (17 boys and 23 girls). The mean values in the activator group and the age-related Bolton Standards are also given. Scale in 1-mm steps.

and the chin position changed. These changes are most likely the result of a stimulation of condylar growth.[17,19,52] Additionally, a remodeling of the glenoid fossa or condylar positional changes within the fossa[17,23,25,53] influencing the amount and direction of effective condylar growth cannot be excluded.

The Co point changes found in the present study were similar to those reported earlier.[19,23,53] Hultgren et al[52] described both increased vertical and sagittal condylar growth in treated compared to untreated class II, division I patients. Pancherz[9] even found an increased posterior displacement of point articulare in his activator patients when comparing them to the Bolton Standards. In the present sample, however, the vertical components of effective condylar growth and chin position change were affected, in contrast to the increased mandibular prognathism mainly sought by activator treatment.

The stronger caudal displacement of Pg in the activator group, in comparison with the Bolton group, was probably caused by the treatment approach itself since the activator

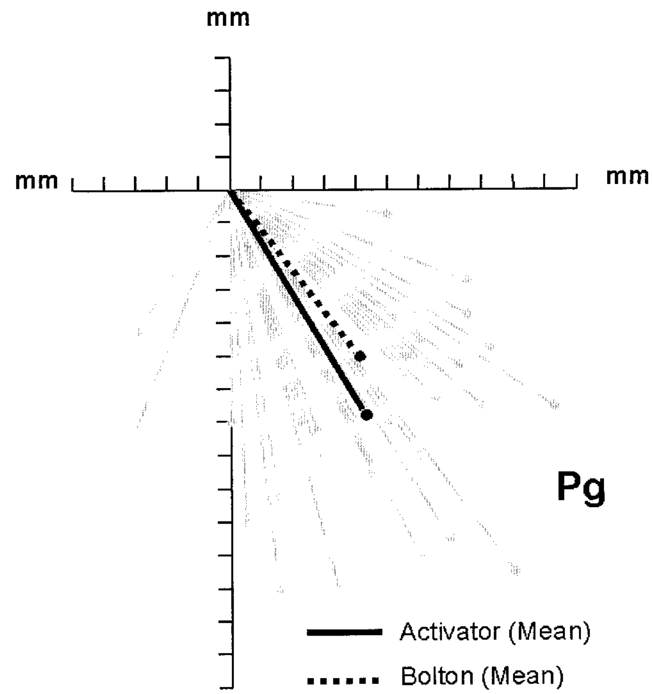

FIGURE 7. Overall growth changes (individual values). Chin position changes in 40 activator patients (17 boys and 23 girls). The mean values in the activator group and the age-related Bolton Standards are also given. Scale in 1-mm steps.

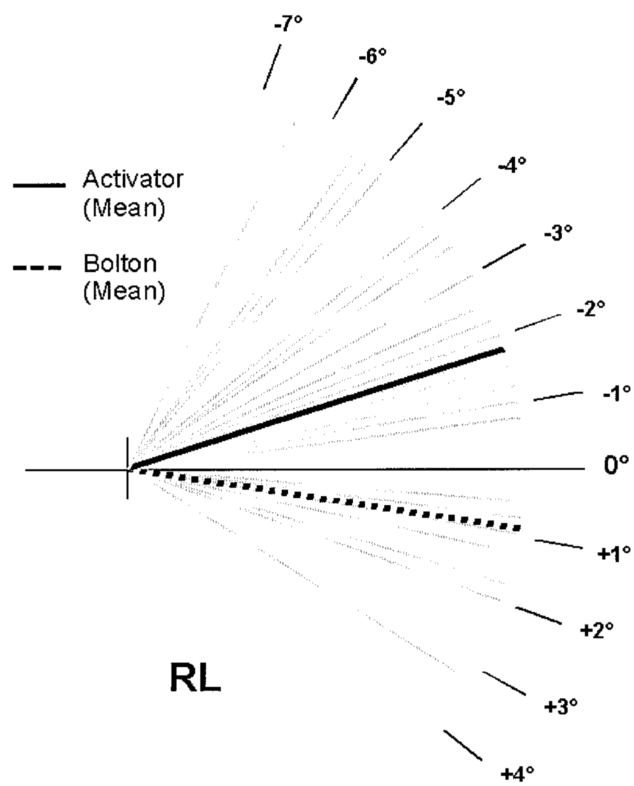

FIGURE 8. Overall growth changes (individual values). Mandibular inclination changes in 40 activator patients (17 boys and 23 girls). The mean values in the activator and the age-related Bolton Standards are also given. Scale in 1-mm steps.

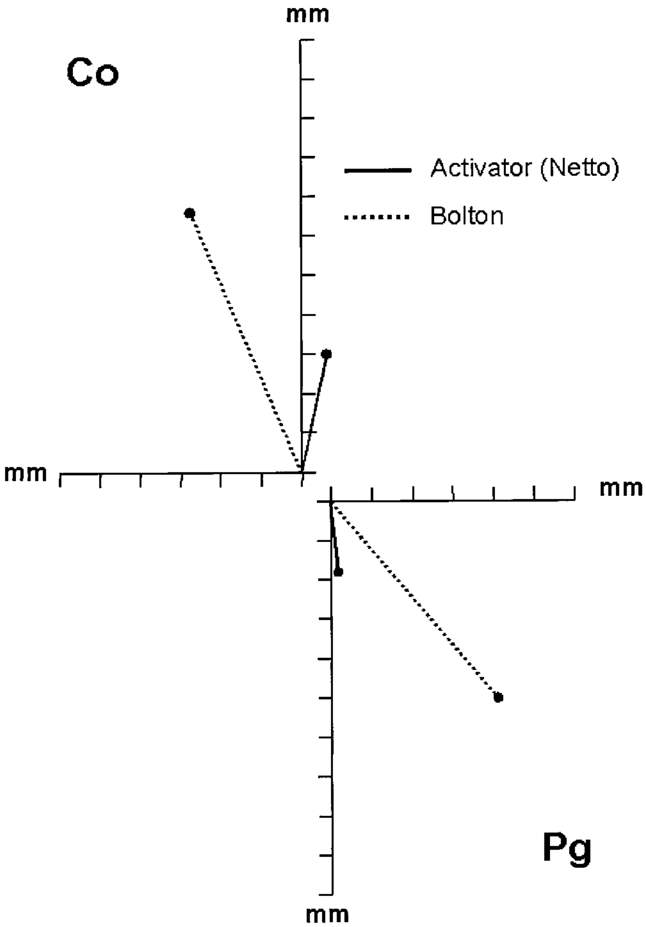

FIGURE 9. Treatment effects (mean values). Effective condylar growth and chin position changes in 40 activator patients (17 boys and 23 girls). The average physiological growth of the Bolton Standards is also shown. Scale in 1-mm steps.

displaced the mandible caudally along the path of incisal guidance. Additionally, the trimming of the activator allowing for an eruption of molars and premolars also might have contributed to a vertical jaw development. Furthermore, a basic vertical growth pattern in the Class II, division 1 subjects[41,54–56] cannot be excluded.

No increased sagittal displacement of the Pg point could be found in the activator group compared with the Bolton group. Pancherz,[9] on the other hand, reported larger sagittal changes in his activator patients.

During the observation period, an anterior mandibular rotation was seen in the activator group in contrast to the slight posterior rotation in the Bolton group. Hultgren et al[52] attributed an anterior or posterior rotation of the mandible to a discrepancy in the development of the anterior and posterior facial heights. The relatively increased vertical development of the Co point in the present activator group was thus probably responsible for the stronger anterior mandibular rotation when compared with the Bolton group. Pancherz et al[36] showed that during functional appliance treatment, the direction of displacement of the Pg point equals that of the Co point if no mandibular rotation takes place.

Treatment effects

The treatment effects also showed that effective condylar growth was increased and the chin position changed by activator therapy. However, neither the condylar nor the chin changes were in the desired (sagittal) therapeutic direction. On the contrary, the chin position changes in particular were almost exclusively vertical. Thus, as a class I molar relationship was achieved in all activator patients despite the missing sagittal skeletal therapeutic growth component, the correction of the class II malocclusion was most probably the result of dentoalveolar changes.

CONCLUSION

The present investigation demonstrates that effective condylar growth and the chin position can be affected by activator therapy. This implies that activator therapy has a skeletal treatment effect. However, probably because of the lack of sagittal directed effective condylar growth, no increase in mandibular prognathism beyond the amount to be expected by physiological growth could be accomplished.

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