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78th Anniversary 1930–2008

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The Angle Orthodontist: **Vol. 71, No. 2, pp. 120–126.**

Effects of Early Activator Treatment in Patients with Class II Malocclusion Evaluated by Thin-Plate Spline Analysis

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ABSTRACT

The aim of the present longitudinal cephalometric study was to evaluate the dentofacial shape changes induced by activator treatment between 9.5 and 11.5 years in male Class II patients. For a rigorous morphometric analysis, a thin-plate spline analysis was performed to assess and visualize dental and skeletal craniofacial changes. Twenty male patients with a skeletal Class II malrelationship and increased overjet who had been treated at the University of Heidelberg with a modified Andresen–Häupl-type activator were compared with a control group of 15 untreated male subjects of the Belfast Growth Study. The shape changes for each group were visualized on thin-plate splines with one spline comprising all 13 landmarks to show all the craniofacial shape changes, including skeletal and dento-alveolar reactions, and a second spline based on 7 landmarks to visualize only the skeletal changes. In the activator group, the grid deformation of the total spline pointed to a strong activator-induced reduction of the overjet that was caused both by a tipping of the incisors and by a moderation of sagittal discrepancies, particularly a slight advancement of the mandible. In contrast with this, in the control group, only slight localized shape changes could be detected. Both in the 7- and 13-landmark configurations, the shape changes between the groups differed significantly at $P < .001$. In the present study, the morphometric approach of thin-plate spline analysis turned out to be a useful morphometric supplement to conventional cephalometrics because the complex patterns of shape change could be suggestively visualized.

KEY WORDS: Thin-plate spline analysis, Morphometrics, Class II malocclusion, Activator treatment.

Accepted: March 2000.

INTRODUCTION Return to TOC

In the last few decades, many investigations have been carried out to evaluate the effects of activator therapy on dental and skeletal structures in patients with Class II malocclusion. In this context, one of the main questions has been whether the growth of the craniofacial skeleton, specifically the location and size of the mandible, can be influenced by orthodontic therapy during a comparatively short period of craniofacial development.[1]

For a detailed review of the literature concerning therapeutic growth modifications in Class II malocclusions, the reader is referred to the surveys of Tulloch et al,[2] Bishara and Ziaja,[3] Aelbers and Dermaut,[1] and Barton and Cook.[4] Bishara and Ziaja[3] concluded that there is still no consensus about the mechanisms involved here, especially the degree to which dento-alveolar or skeletal components can be influenced.

New morphometrics and thin-plate spline analysis

In nearly all existing cephalometric studies dealing with the mechanisms of Class II correction, angles, linear measurements, or ratios have been used to assess craniofacial changes. Moyers and Bookstein[5] clearly expounded the fundamental limitations of this common cephalometric approach. As any measured angle is a function of 3 points of 2 coordinates each (in all, 6 degrees of freedom), growth movements of all 3 points can affect the change of an angle. Thus, interpretation with respect to the underlying growth processes is difficult since different patterns of deformation may result in similar angular changes.[6]

In the subsequent years, novel morphometric approaches, such as tensor analysis, finite-element methods, and shape- coordinate techniques[6–10] as well as the Euclidean distance matrix analysis,[11] provided methodical progress in morphometrics. Nevertheless, tensor analysis and related techniques require, as a rule, an a priori construction of triangles on the basis of landmarks, which leads to considerable arbitrariness and impedes the recognition of global growth effects such as uniform shape changes.[12,13]

In 1989, Bookstein[14] introduced a new morphometric method for shape comparisons, namely the thin-plate spline analysis. The basic principle of this technique is modeling biological shape differences between 2 configurations of landmarks as a continuous deformation analogous to the bending of an infinitely thin metal plate.[14] In the field of dentofacial orthopedics, this new morphometric approach has been gaining increasing importance. For instance, Pae et al[15] used thin-plate spline analysis to investigate the shape characteristics of the face and tongue in obstructive sleep apnea. Singh et al[16,17] examined the role of the cranial base and the morphological differences of mandibular shape in Class III malocclusions by means of thin-plate spline analysis. In addition, the characteristics of soft-tissue profiles in Class III patients were investigated using this morphometric approach.[18,19] Baccetti et al[20] also demonstrated the usefulness of thin-plate spline analysis in a longitudinal cephalometric comparison between a treated and an untreated Class III patient group.

The aim of this longitudinal cephalometric study was to evaluate dentofacial shape changes in Class II patients induced by early activator treatment. In addition, the potential of the new morphometric approach of thin-plate spline analysis was to be used to assess dental as well as skeletal craniofacial changes, particularly against the background that the mechanisms of correcting a Class II malocclusion and skeletal discrepancy are still controversial.

MATERIALS AND METHODS Return to TOC

Study design and data collection

In this longitudinal cephalometric study, male patients with a skeletal Class II malrelationship and increased overjet who had been treated at the University of Heidelberg were compared with a group of untreated male subjects of the Belfast Growth Study.[21] Both the treated patients and the untreated controls had to meet the following inclusion criteria:

1. ANB angle ≧ 5° in the initial lateral cephalogram,
2. overjet ≧ 5 mm in the initial lateral cephalogram,
3. first cephalogram taken at age 9.5 ± 1 years,
4. second cephalogram taken at age 11.5 ± 1 years,
5. time interval between the 2 cephalograms of 2 ± 1 years,

The activator group consisted of 20 patients who were treated without extraction of teeth with a modified Andresen–Häupl-type activator in the respective 2-year interval, as shown in Figure 1. The construction bite was taken with teeth in neutralocclusion and with an approximate vertical increase in the molar region of about 4–5 mm. Patients were excluded from the study if there was a hint of a repeated insufficient compliance during activator treatment, especially concerning the recommendation to wear the appliance about 14 hours a day.

Fifteen male untreated probands from the Belfast Growth Study, the material for which had been collected by Professor C. P. Adams at the Queens University of Belfast, served as a control group. The ages of the treated and untreated children when the lateral cephalograms were taken were, for the activator group, t_1 = 9.48 ± 0.69 years and t_2 = 11.68 ±0.46 years, and for the control group, t_1 = 9.50 ± 0.37 years and t_s = 11.32 ± 0.38 years.

Cephalometric analysis

For the cephalometric analysis, the landmarks shown in Figure 2 were identified. All the cephalograms had been traced first, and subsequently the coordinates of the landmarks were registered by means of a digitizing tablet (Calcomp). Replicate tracings of 10 lateral cephalograms were used for evaluating the measurement error according to Dahlberg's formula.[22] The combined error of the method concerning landmark location and accuracy of measurement was calculated for the *x*-coordinate (parallel to sella-nasion line) and for the *y*-coordinate (vertical to sella-nasion line) of each of the 15 landmarks. No landmark displayed an error larger than 1 mm. The landmarks sella and gnathion showed the smallest errors, being within the range 0.2–0.3 mm both in the *x* and *y* directions. The landmarks upper incisor apex and lower incisor apex displayed the largest errors, being around 0.8 mm in either the *x* or *y* directions.

The coordinates of the landmarks provided the data base for the computation of the thin-plate splines and the conventional cephalometric analysis.

Thin-plate spline analysis

For a geometrical and graphical description of the shape changes occurring in the activator and the control groups, a thin-plate spline analysis[12,14] was performed. Thin-plate spline analysis is an interpolation technique inspired by the theory of the bending of an infinitely thin metal plate. It mathematically realizes the idea that, when a metal plate is fixed at certain heights vertical to the plane, it tends toward a form of minimal energy, ie, the form of minimal curvature.

In the cephalometric context, changes between 2 configurations of landmarks can be depicted by a pair of splines, with one spline representing the change in the *x*-coordinate of each landmark and the other one the change in the *y*- coordinate.[14] The combination of these 2 splines yields a transformation of the plane that maps each landmark of the initial configuration to the respective homologue landmark of the final configuration. In this way, biological shape change is modeled as a deformation and the spatial changes between the 2 sets of landmarks can be visualized by means of transformation grids.[14]

The deformation between 2 sets of landmarks can be decomposed into an affine part and an affine-free part. The affine part corresponds to a tilting or lifting, not a bending of the metal plate, thus not affecting bending energy.[14]

The nonaffine part describes the local deformations and can be decomposed into a series of progressively localized components.

The initial landmark configuration defines a series of $n - 3$ orthogonal functions, the so-called principal warps, where n is the number of landmarks. They are calculated from the eigenvectors of the bending energy matrix and describe the change of shape at different geometric scales.

The principal warps serve as a basis for the shape changes between the 2 landmark configurations. The nonaffine part of the deformation can be projected on the principal warps, and the resulting decomposition of shape change leads to the partial warps, which are again deformations in the plane. Hence, each partial warp is the contribution of the corresponding principal warp to the total spline. The coordinates in the basis of the principal warps are called partial-warp scores and are appropriate for a statistical testing of the shape changes between the 2 groups.[23]

In this study, the thin-plate splines were calculated using the program tpspline.[24] For both the activator and the control group at t_1 and t_2, a scaled (with the so-called centroid size[12] as scaling factor) average configuration of landmarks was computed based on the generalized least-squares orthogonal Procrustes analysis.[25] In the next step, the shape changes between t_1 and t_2 were displayed for both groups by means of thin-plate splines. For a description of the whole craniofacial shape changes, a set of 13 cephalometric landmarks (cf Figure 1) was used to show dental as well as skeletal shape changes (the landmarks pogonion and menton were omitted in the spline depiction due to the redundancy of data). In addition, a second spline based on the 7 landmarks nasion, sella, gonion, gnathion, articulare and anterior and posterior nasal spines was used to show up the skeletal shape changes in both groups without the depiction of any dental component.

In addition to the visual inspection of the shape changes in both groups by means of thin-plate splines, a multivariate statistical analysis based on the matrices of partial-warp scores[23] was used to test for differences in the shape changes from t_1 to t_2 in both groups. On the basis of net Procrustes distance, a matched version of a permutation test[24] was used for the comparison of the differences in the partial-warp scores representing the shape change (including the uniform term) in each group.

Conventional cephalometric analysis

For better comparability with the results of former cephalometric studies, thin-plate spline analysis was supplemented by a conventional cephalometric analysis. The variables shown in Tables 1 and 2 were used. First, a comparison at baseline (t_1) was performed between both groups using Wilcoxon's rank sum test. A nonparametric test was used in order to perform conservative hypothesis testing. In a second step, the same procedure was used to test for statistical significance concerning the changes between the 2 groups.

RESULTS Return to TOC

Thin-plate spline analysis

The splines shown in Figure 3 visualize, both for the activator and the control group, the whole craniofacial shape changes between the average configurations at 9.5 and 11.5 years. In the activator group, a pronounced reduction of overjet is visualized by a horizontal compression of the grid between the edges of the upper and lower incisors (Figure 3a). In addition, the pattern of grid deformation points to a marked retrusion of the upper incisors as well as an additional protrusion of the lower incisors, thus suggesting a considerable dento-alveolar contribution to overjet correction. In Figure 3a, the retrusion of the upper incisors is suggestively visualized by means of the bending of the grid in the region of the upper incisor edges. In addition, an anteriorly directed stretching of the grid is visible in the mandibular region, which is also shown—more clearly—in the 7-landmark configuration (Figure 4a). In the activator group, the pattern of grid deformation points out comparatively slight shape changes in the vertical dimension in contrast with a marked antero-posterior compression or stretching.

By contrast, in the thin-plate spline analysis of the control group (Figure 3a), the grid lines deviate only marginally from straight lines, indicating merely slight local, nonaffine deformations especially affecting the region between the A point and the anterior nasal spine. The total spline is affected by a homogeneous shear rather than by pronounced localized shape changes (Figure 4a). In the multivariate statistical analysis, the shape changes based on the configuration of 13 landmarks differ significantly at $P < .001$.

In the spline depiction of the configuration of the 7 landmarks (Figure 4a,b), the differences concerning the mere skeletal reactions are visualized more distinctly since the rather strong tippings of the incisors, which markedly influence the grid transformation, are omitted. In the activator group (Figure 4a), an anteriorly directed bending of the grid lines can be seen in the intermaxillary region, which points to an intermaxillary positional change, particularly a slight advancement of the mandible. This pattern of shape change differs significantly at $P < .001$ from the control group (Figure 4b), where the shape changes are dominated by a uniform component rather than by more localized intermaxillary shape changes.

Conventional cephalometric analysis

As a first step, the 2 groups were compared at baseline (9.5 years). Table 1 shows the results of the Wilcoxon's rank sum test. Statistically significant differences between the 2 groups were found in the extent of overjet and in the inclination of the upper incisors. At the beginning of treatment in the activator group, the upper incisors are more proclined and the overjet is significantly larger (mean 9.5 mm) than in the control group (mean 7.1 mm). No significant differences were found in the sagittal and vertical relationships ($P > .05$).

As a next step, it was tested whether the changes of the cephalometric variables in both groups differ significantly. Table 2 shows the results of Wilcoxon's rank sum test. In the activator group, a pronounced uprighting of the proclined incisors is evident, in contrast with the control group, where this effect is negligible. Moreover, the lower incisors procline more in the activator group than in the control group. Here, the strong grid deformations in the dento-alveolar area shown in the spline analysis correspond to the changes in the angular measurements. In this way, the conventional cephalometric analysis underlines the strong dento-alveolar component in overjet correction.

As far as the changes in sagittal relationships are concerned, an ANB reduction of 1.38° is found in the activator group, which differs significantly ($P < .05$) from the decrease of 0.54° in the control group. Similarly, the increase in the SNB angle is significantly larger ($P < .001$) in the activator group than in the control group. In the case of the SNA angle, the changes between the 2 groups do not differ significantly. Moreover, no significant differences were found between the 2 groups concerning vertical relationships. This corresponds to the observation that, in both groups, the grid lines in the respective spline transformations show next to no change in the vertical dimension.

DISCUSSION Return to TOC

In the present cephalometric study, a thin-plate spline analysis and a conventional cephalometric analysis were undertaken to visualize the dental and skeletal changes during activator treatment at an early stage of development, usually well before the pubertal growth spurt commenced. As Barton and Cook[4] pointed out, functional appliances are becoming increasingly important in a 2-phase therapy concept for Class II malrelationships. After a period of correcting sagittal discrepancies with a functional appliance, the remaining treatment needs (eg, a further reduction of overjet or tooth alignment) are carried out by means of fixed appliances. Hence, it seemed clinically interesting to evaluate the effectiveness of activator treatment during the first phase of Class II therapy in the mixed dentition using extended morphometric methods.

Study design

In the interpretation of the results, ie, determining to what degree the changes observed can be attributed to treatment and not to growth processes, the small sample sizes, especially of the control group, and the retrospective study design must be taken into account. As Tulloch et al[2] pointed out, in retrospective studies, the treatment group usually consists of patients who were considered to respond favorably to the treatment intended. This source of bias due to nonrandomized treatment assignment may introduce dissimilarities between the samples and, in addition, impair the comparability of studies of different investigators.[2]

Thin-plate spline analysis and treatment effects

In the present study, the use of thin-plate spline analysis seemed to be valuable because the depiction of shape changes by transformation grids following the spirit of Thompson[26] allows for a suggestive visualization of the underlying patterns of shape change. In addition, this morphometric technique makes possible a separation of size differences and uniform shape changes from those changes describing inhomogeneous nonaffine or local deformations.[12,13] As Rohlf and Marcus[13] pointed out, it must be stressed that the use of splines does not imply that biological tissues behave like metal sheets but that spline functions are able to depict the differences in 2 configurations of landmarks as a continuous deformation.

In the present study, the activator turned out to be a valuable tool for the reduction of overjet and, to a certain degree, for a moderation of sagittal discrepancies. The grid deformation of thin-plate spline analysis suggests a comparatively strong dento-alveolar component that is marked by a retroclination of the upper incisors and a moderate proclination of the lower incisors. However, the angular change of the lower incisor inclination compared with the untreated controls does not reach statistical significance. Both the spline analysis and the conventional cephalometric analysis point to an additional skeletal mechanism altering the relative mandibular-maxillary position, which is mainly characterized by a skeletal mandibular reaction during the 2-year interval.

Bishara and Ziaja[3] summarized the results of numerous studies on different modes of Class II activator action, inferring that probably a combination of orthodontic (60– 70%) and orthopedic (30–40%) movements is responsible for treatment success—a conclusion that is roughly in keeping with the results of the morphometric approach in the present study. However, predicting individually the extent of a possible skeletal response to activator treatment is impeded by the wide dentofacial morphological variation within the Class II division 1 malocclusion. Those patients show their own unique individual growth patterns,[27] which again results in a wide individual variation in treatment response.[28]

CONCLUSIONS Return to TOC

Within the limits of this retrospective study, the following conclusions can be drawn:

1. Thin-plate spline analysis seems to provide a valuable supplement for conventional angular analyses because the complex patterns of shape change are visualized suggestively by means of grid deformations, thus opening up a wide field of possible applications in cephalometrics.
2. In male subjects exhibiting a Class II skeletal discrepancy, the Andresen–Häupl-type activator seems to be a suitable tool for overjet reduction and a moderation of sagittal discrepancies. Thin-plate spline analysis supports the hypothesis that dento-alveolar mechanisms seem to play an important role in this correction but also suggests a relative mandibulo-maxillary displacement, mainly a mandibular advancement. In future, additional studies with a prospective study design are called for, also with respect to the long-term stability of the dental and skeletal changes.

ACKNOWLEDGMENTS

We wish to express our gratitude to Professor Fred L. Bookstein, University of Michigan, for his advice on statistical testing and related matters. In addition, we want to thank Professor Andrew Richardson, Professor Emeritus of the Queens University of Belfast, for permitting access to the material of the Belfast Growth Study.

REFERENCES Return to TOC

1. Aelbers CMF, Dermaut LR. Orthopedics in orthodontics: fiction or reality. A review of the literature—part I. *Am J Orthod Dentofac Orthop.* 1996; 110:513–519.

2. Tulloch JFC, Medland W, Tuncay OC. Methods used to evaluate growth modification in Class II malocclusion. *Am J Orthod Dentofac Orthop.* 1990; 98:340–347.

3. Bishara SE, Ziaja RR. Functional appliances: a review. *Am J Orthod Dentofac Orthop.* 1989; 95:250–258.

4. Barton S, Cook PA. Predicting functional appliance treatment outcome in Class II malocclusions—a review. *Am J Orthod Dentofac*

Orthop. 1997; 112:282–286.

5. Moyers RE, Bookstein FL. The inappropriateness of conventional cephalometrics. *Am J Orthod.* 1979; 75:599–617. [PubMed Citation]

6. Richtsmeier JT, Cheverud JM. Finite element scaling analysis of human craniofacial growth. *J Craniofac Genet Dev Biol.* 1986; 6:289–323. [PubMed Citation]

7. Bookstein FL. *The Measurement of Biological Shape and Shape Change.. Lecture Notes in Biomathematics.* Vol. 24. Berlin: Springer; . 1978;

8. Bookstein FL. On the cephalometrics of skeletal change. *Am J Orthod.* 1982; 82:177–198. [PubMed Citation]

9. Bookstein FL. Tensor biometrics for changes in cranial shape. *Ann Hum Biol.* 1984; 11:413–437. [PubMed Citation]

10. Moss ML, Skalak R, Patel H, Sen K, Moss-Salentijn L, Shinozuka M, Vilmann H. Finite element method modeling of craniofacial growth. *Am J Orthod.* 1985; 87:453–472. [PubMed Citation]

11. Lele S, Richtsmeier JT. Euclidean distance matrix analysis: a coordinate-free approach for comparing biological shapes using landmark data. *Am J Phys Anthropol.* 1991; 86:415–427. [PubMed Citation]

12. Bookstein FL. *Morphometric Tools for Landmark Data.*. New York, NY: Cambridge University Press; . 1991;

13. Rohlf FJ, Marcus LF. A revolution in morphometrics. *Trends Ecol Evol.* 1993; 8:129–132.

14. Bookstein FL. Principal warps: thin-plate splines and the decomposition of deformations. *IEEE Trans Pattern Anal Machine Intelligence.* 1989; 11:567–585.

15. Pae EK, Lowe AA, Fleetham JA. A thin-plate spline analysis of the face and tongue in obstructive sleep apnea patients. *Clin Oral Invest.* 1997; 1:178–184.

16. Singh GD, McNamara JA Jr, Lozanoff S. Thin-plate spline analysis of the cranial base in subjects with Class III malocclusion. *Eur J Orthod.* 1997; 19:341–353. [PubMed Citation]

17. Singh GD, McNamara JA Jr, Lozanoff S. Spline analysis of the mandible in human subjects with Class III malocclusion. *Arch Oral Biol.* 1997; 42:345–353. [PubMed Citation]

18. Singh GD, McNamara JA Jr, Lozanoff S. Components of soft- tissue deformations in subjects with untreated angle's Class III malocclusions: thin-plate spline analysis. *J Craniofac Genet Dev Biol.* 1998; 18:219–227. [PubMed Citation]

19. Singh GD, McNamara JA Jr, Lozanoff S. Soft tissue thin-plate spline analysis of pre-pubertal Korean and European-Americans with untreated angle's Class III malocclusions. *J Craniofac Genet Dev Biol.* 1999; 19:94–101. [PubMed Citation]

20. Baccetti T, Franchi L, McNamara JA. Thin-plate spline analysis of treatment effects of rapid maxillary expansion and face mask therapy in early Class III malocclusions. *Eur J Orthod.* 1999; 21:275–281. [PubMed Citation]

21. Kerr WJS. A longitudinal cephalometric study of dento-facial growth from 5 to 15 years. *Br J Orthod.* 1979; 6:115–121. [PubMed Citation]

22. Dahlberg G. *Statistical Methods for Medical and Biological Students.*. New York, NY: Interscience; . 1940;

23. Rohlf FJ, Loy A, Corti M. Morphometric analysis of old world Talpidae (Mammalia, Insectivora) using partial-warp scores. *Syst Biol.* 1996; 45:344–362.

24. Rohlf FJ. *Tpsspline,* Ver. 1.14; *Tpsregr,* Ver. 1.18. Stony Brook, NY: University of New York (Life.Bio.SUNYSB.edu/morph); . 1997;

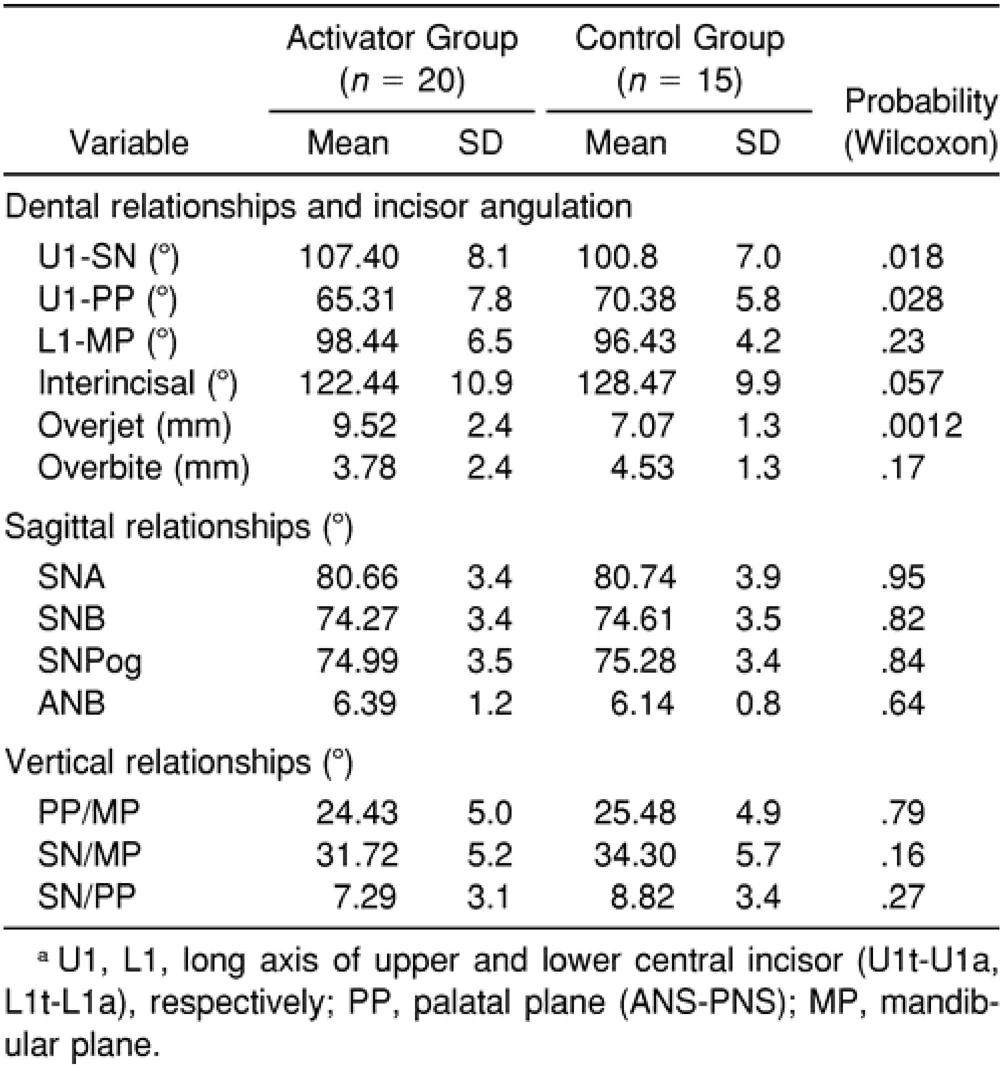
25. Rohlf FJ, Slice D. Extensions of the Procrustes method for the optimal superimposition of landmarks. *Syst Zool.* 1990; 39:40–59.

26. Thompson D' AW. *On Growth and Form.*. London: Cambridge University Press; . 1917;

27. Bishara SE, Zaher AR, Cummins DM, Jakobson JR. Effects of orthodontic treatment on the growth of individuals with Class II division 1 malocclusion. *Angle Orthod.* 1994; 64:221–230. [PubMed Citation]

28. Vargervik K, Harvold EP. Response to activator treatment in Class II malocclusions. *Am J Orthod.* 1985; 88:242–51. [PubMed Citation]

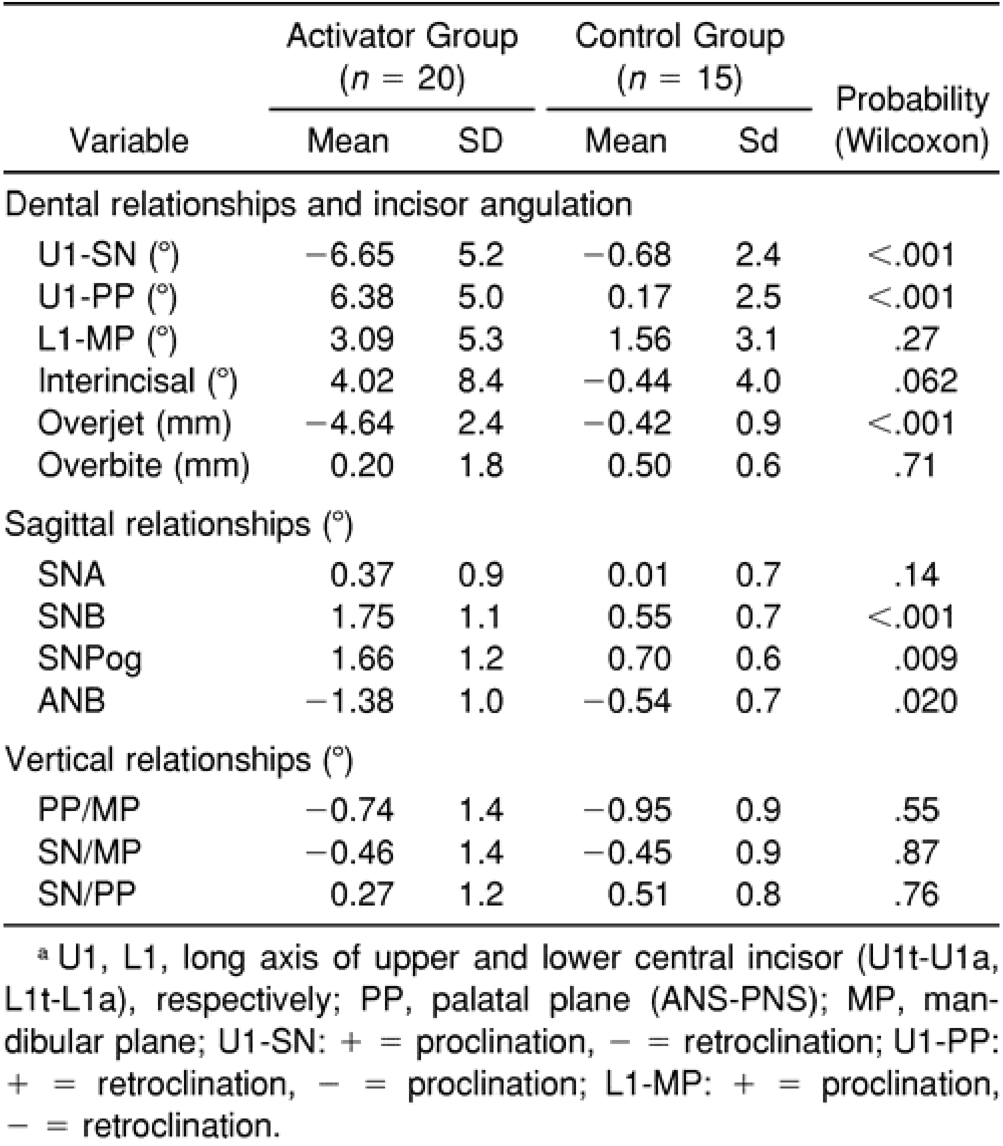
TABLE 1. Comparison of Initial Values at Baseline (t_1)(Test for Pre~ treatment Equivalence)[a]



Variable	Activator Group (*n* = 20) Mean	Activator Group (*n* = 20) SD	Control Group (*n* = 15) Mean	Control Group (*n* = 15) SD	Probability (Wilcoxon)
Dental relationships and incisor angulation					
U1-SN (°)	107.40	8.1	100.8	7.0	.018
U1-PP (°)	65.31	7.8	70.38	5.8	.028
L1-MP (°)	98.44	6.5	96.43	4.2	.23
Interincisal (°)	122.44	10.9	128.47	9.9	.057
Overjet (mm)	9.52	2.4	7.07	1.3	.0012
Overbite (mm)	3.78	2.4	4.53	1.3	.17
Sagittal relationships (°)					
SNA	80.66	3.4	80.74	3.9	.95
SNB	74.27	3.4	74.61	3.5	.82
SNPog	74.99	3.5	75.28	3.4	.84
ANB	6.39	1.2	6.14	0.8	.64
Vertical relationships (°)					
PP/MP	24.43	5.0	25.48	4.9	.79
SN/MP	31.72	5.2	34.30	5.7	.16
SN/PP	7.29	3.1	8.82	3.4	.27

[a] U1, L1, long axis of upper and lower central incisor (U1t-U1a, L1t-L1a), respectively; PP, palatal plane (ANS-PNS); MP, mandibular plane.

TABLE 2. Changes in the Activator Group Compared with the Un~ treated Control Group[a]



Variable	Activator Group (*n* = 20)		Control Group (*n* = 15)		Probability (Wilcoxon)
	Mean	SD	Mean	Sd	
Dental relationships and incisor angulation					
U1-SN (°)	−6.65	5.2	−0.68	2.4	<.001
U1-PP (°)	6.38	5.0	0.17	2.5	<.001
L1-MP (°)	3.09	5.3	1.56	3.1	.27
Interincisal (°)	4.02	8.4	−0.44	4.0	.062
Overjet (mm)	−4.64	2.4	−0.42	0.9	<.001
Overbite (mm)	0.20	1.8	0.50	0.6	.71
Sagittal relationships (°)					
SNA	0.37	0.9	0.01	0.7	.14
SNB	1.75	1.1	0.55	0.7	<.001
SNPog	1.66	1.2	0.70	0.6	.009
ANB	−1.38	1.0	−0.54	0.7	.020
Vertical relationships (°)					
PP/MP	−0.74	1.4	−0.95	0.9	.55
SN/MP	−0.46	1.4	−0.45	0.9	.87
SN/PP	0.27	1.2	0.51	0.8	.76

[a] U1, L1, long axis of upper and lower central incisor (U1t-U1a, L1t-L1a), respectively; PP, palatal plane (ANS-PNS); MP, mandibular plane; U1-SN: + = proclination, − = retroclination; U1-PP: + = retroclination, − = proclination; L1-MP: + = proclination, − = retroclination.

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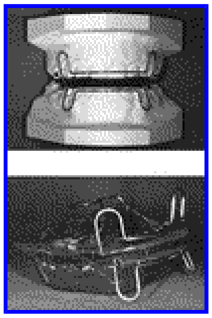

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FIGURE 1. Modified Andresen–Häupl-type activator. For better control of lower incisor inclination, the lower incisors are covered with acrylic, which is relieved on the lingual surface

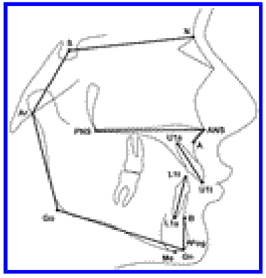

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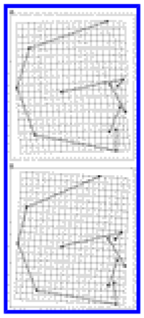
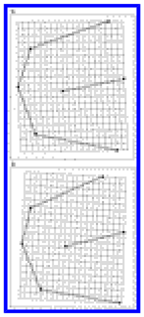
FIGURE 2. Landmarks used for thin-plate splines and angular measurements: nasion (N); sella (S); articulare (Ar); tangent gonion (Go); menton (Me); gnathion (Gn); pogonion (Pog); A and B points, anterior and posterior nasal spines (ANS, PNS); upper and lower incisor apex (U1a, L1a), upper and lower incisor tips (U1t, L1t)



Click on thumbnail for full-sized image.

FIGURE 3. Configuration of 13 landmarks: thin-plate spline depiction of the craniofacial shape changes comprising the affine and nonaffine parts of the deformation in the activator group (a) and the control group (b)



Click on thumbnail for full-sized image.

FIGURE 4. Configuration of 7 landmarks: thin-plate spline depiction of the craniofacial shape changes comprising the affine and nonaffine parts of the deformation in the activator group (a) and the control group (b)