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Evaluation of the variable anchorage straightwire technique using Ricketts' growth prediction

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SUMMARY The purpose of this retrospective study was to evaluate the treatment effects of the variable anchorage straightwire technique (VAST) in Angle Class II patients using Ricketts' growth prediction analysis. The subjects belonged to two groups: a control, consisting of 30 untreated Class II Swedish individuals (20 girls, 10 boys) with a mean age of 11.2 years, and the other 29 Swedish patients (14 girls, 15 boys), mean age 12.6 years, post-normal and with an increased overbite (OB), treated with the VAST. Two lateral cephalograms were available for every individual.

Growth prediction according to Ricketts' visual treatment objective (VTO) was used to estimate the expected growth increments for a 2-year period. It was first used in the control group to determine its validity and then applied to the treated group to evaluate the net effects of treatment. Cephalometric evaluation based on Ricketts' analysis and additional dentoalveolar variables were carried out. Statistical analysis was undertaken using a paired Student's *t*- and Wilcoxon signed ranks tests.

The method of predicting growth according to the VTO was, in general, valid in the untreated subjects, apart from the inclination of the lower incisors, where the proclination had been underestimated. In the treated group, the net effects of treatment were significant for the dentoalveolar variables: reduction of overjet (OJ) and OB, proclination and relative intrusion of the lower incisors, extrusion of the molars, and increase in lower face height.

The growth prediction method according to VTO was found to be valid in a sample of Swedish post-normal children concerning skeletal and dentoalveolar variables. The VAST treatment net effects in these growing patients were achieved mainly by dentoalveolar changes.

Introduction

Treatment of a Class II malocclusion with an increased overbite (OB) constitutes a significant percentage of everyday clinical practice. In a Caucasian child population, the frequency of a Class II malocclusion is approximately 18.5 per cent and of a deep bite (OB ≥ 5 mm) 7.4 per cent (Ingervall *et al.*, 1972). The need for treatment is relatively high due to preventive, functional, aesthetic, and, sometimes, psychological reasons.

Orthodontic treatment of these patients, however, is quite demanding concerning anchorage need and opening of the bite. The main advantage of the Begg technique is an effective correction of the deep bite with minimal anchorage demand, while the edgewise technique provides precise and easier control of tooth positioning in three dimensions. Therefore, early trials focused on the development of a combination technique (Perlow, 1967; Fogel and Magill, 1969; DeAngelis, 1976; Hocevar, 1985; Thompson, 1988, 1995; Kesling, 1989). The main purpose was to retain the tipping–uprighting mechanics from the Begg technique and the advantage of rectangular archwires in a horizontal slot for the finishing stage from the edgewise technique, avoiding the additional use of intraoral anchorage appliances or extraoral forces.

A recent and complete combination method is the variable anchorage straightwire technique (VAST; Thompson, 1995; Zuriarrain *et al.*, 1996; Banaie *et al.*, 2005) with the use of special archwires and a specially designed bracket which has a combination of gingival, occlusal, vertical, and straightwire slots. The treatment consists of four stages, where the anterior relationships are first corrected, followed by the posterior segments and the necessary root torque. Class II elastic are often needed, and the treatment can include extractions of teeth when necessary (Fig. 1).

Even if the VAST seems effective clinically, its influence on skeletal and dental components during treatment is unknown.

However, during treatment of children, a certain amount of growth of the craniofacial complex takes place. Using matched control groups, it is possible to obtain an estimation of the growth for a specific time period (Johnston, 1975; Schulhof and Bagha, 1975). Among the most successful is the prediction of growth according to the visual treatment objective (VTO; Ricketts *et al.*, 1979a), having the additional advantage of taking into consideration the individual skeletal pattern rather than a proposed mean pattern for the specific chronological age. The accuracy of the method for mandibular growth is up to 78 per cent (Schulhof and Bagha, 1975). Kocadereli and Telli (1999) tested the prediction method for a period of 7 years in Turkish children and reported accurate predictions for most skeletal measurements, but less accuracy concerning soft tissue

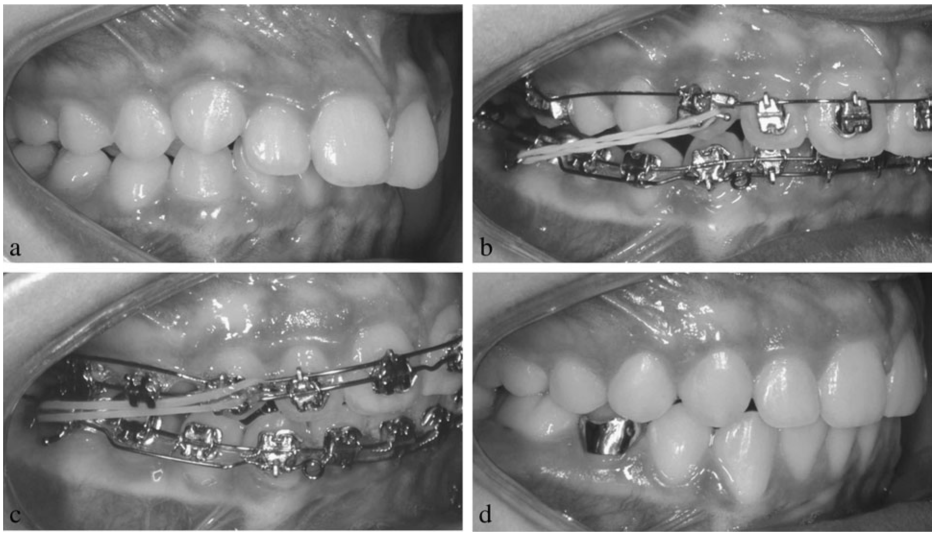

Figure 1 Intraoral photographs of a Class II division 1 patient treated with the variable anchorage straightwire technique, (a) initial, (b and c) under treatment, (d) retention.

variables. Other investigations examined the accuracy of VTO as a whole, both growth and treatment prediction (Thames *et al.*, 1985; Sample *et al.*, 1998; Toepel-Sievers and Fischer-Brandies, 1999), revealing high accuracy for skeletal, moderate for dental, and low for soft tissue measurements.

The main purpose of this retrospective study was therefore, on the basis of VTO analysis, to estimate the growth and evaluate the net treatment effects in Class II patients treated with the VAST. To be able to fulfil the above aims, two evaluations, one of growth prediction and the other of treatment effects, were performed:

1. VTO analysis for growth prediction was validated in a sample of Caucasian children with untreated Class II malocclusions and with an increased OB.
2. VTO analysis for growth prediction was applied to a VAST treated group of patients with a Class II malocclusion and increased OB and was compared with the cephalometric changes during treatment. This procedure enabled the changes due to growth to be distinguished from those due to treatment.

Subjects and methods

The present study was approved by the ethical committee of Huddinge University Hospital, Stockholm, Sweden (decision 465/01).

A group of 30 untreated Swedish children, 20 females and 10 males, was used as the control. These individuals were selected from existing material of untreated children with a Class II malocclusion from a specialist community clinic to be of similar age as the treated group. These children had refused orthodontic treatment, but were checked by their orthodontist for control of occlusal development. All were post-normal, having a mean overjet (OJ) of 7.8 mm [standard deviation (SD) = 3.1 mm] and a mean OB of 3.3 mm (SD = 1.8 mm). Two lateral cephalograms had been taken for every child at the mean ages of 11.2 and 13.3 years.

A second group of 29 Swedish children, 14 females and 15 males, treated with the VAST (Spectrum™ bracket, Lancer Orthodontics Inc., San Marcos, California, USA) was also used. The well-documented records of patients treated by the same orthodontist (SM) within a period of 5 years were consecutively selected. The mean age was 12.6 years at the beginning of treatment. The duration of treatment varied between 1.3 and 2.7 years. All were post-normal, with an OJ and OB of at least 4 mm, respectively. Thirteen were treated with extractions of two or four premolars and 16 without extractions. Two lateral cephalograms were used, one before and one immediately after active orthodontic treatment, having a mean difference of 2.3 years.

Validation of Ricketts' growth prediction method

The growth changes, which could be expected during the treatment period, were evaluated on the basis of the VTO method for growth prediction (Gugino, 1977; Ricketts *et al.*, 1979a).

The untreated group was used to investigate the validity of the VTO growth prediction. The method was applied on the first cephalogram and expected growth changes during a mean period of 2.1 years were estimated. Subsequently, these changes were compared with the true growth changes during the same mean time period of 2.1 years, which could be recorded by comparison of the first and second cephalogram (Fig. 2).

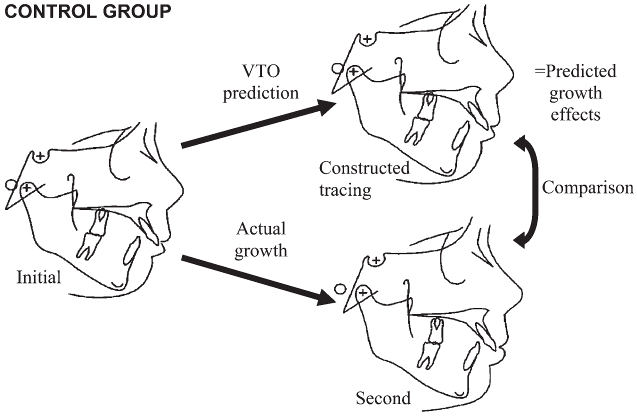

Figure 2 The method used for validation of Ricketts' visual treatment objective (VTO) in the control group. The initial cephalogram was used to produce a constructed tracing according to VTO prediction, and their change was compared with the differences between the initial and second cephalogram representing the actual growth. Time period: 2 years.

For this purpose, a cephalometric analysis based on Ricketts' 11-factor analysis (Ricketts *et al.*, 1979b; Ricketts, 1981), with the addition of extra variables for the evaluation of dentoalveolar changes, was performed. The extra variables registered positional changes of the incisors and first molars and were based on points in the maxilla and mandible which were used during the analysis of the VTO prediction. They were subsequently presumed to follow the same growth changes as in the skeletal pattern. All variables (Fig. 3) were based on points and reference lines on the profile roentgenograms defined by Björk (1947), Solow (1966), and Ricketts *et al.* (1979a). Six skeletal, nine dentoalveolar, and two dental measurements were evaluated, describing both vertical and sagittal skeletal relationships, as well as the position of the upper and lower incisors and first molars (Table 1).

All radiographs were unidentified and randomly traced by the same person (KAP). A computer program, Dento-facial planner 7.02 (Dentofacial Software Inc., Toronto, Ontario, Canada), was used to calculate the cephalometric variables. The linear measurements were corrected according to the magnification factor (7 per cent for the untreated and 10.3 per cent for the treated group).

Distinction of treatment changes

Concerning the treated group, the pre-treatment lateral cephalograms were used for prediction of growth during an average period of 2.3 years by application of the same cephalometric analysis as in the validation of Ricketts' VTO. These changes were then compared with the differences from the pre- to post-treatment lateral cephalograms, representing the combination of growth and treatment, in order to evaluate the net effect of treatment (Fig. 4). For the treated group, the effect of treatment was evaluated separately for the extraction and non-extraction subgroups.

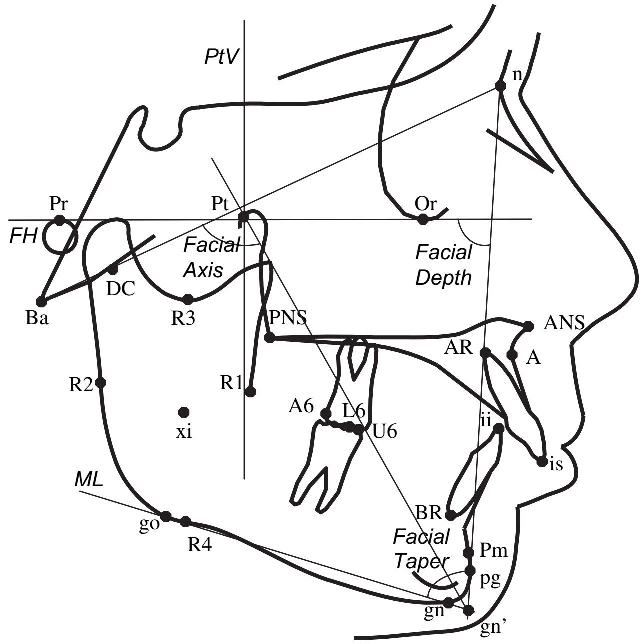

Figure 3 Reference points on a lateral skull radiograph used for growth prediction and cephalometric analysis. The measurements, facial axis, facial depth, and facial taper, according to Ricketts' 11-factor analysis are also shown.

Statistical analysis

Registrations were made on lateral cephalograms and the intra-individual means and SDs were calculated. Descriptive analyses were also made for all cephalometric variables and a normality test (Kolmogorov–Smirnov) was performed. The paired Student's *t*-test for normally distributed variables

Table 1 Variables used in the cephalometric analysis.

Based on Ricketts' 11-factor analysis	
Facial axis (°)	Angle between Ba-n and Pt-gn′ lines
Facial depth (°)	Angle between FH and n-pg lines
Facial taper (°)	Angle between ML and n-pg lines
Mandibular plane to FH (°)	Angle between ML and FH lines
Point A convexity (mm)	Distance of A from the n-pg line
LFH′ angle (°)	ANS-xi-Pm angle
L1 (inclination of lower incisors)/A-Pg (°)	Angle between ii-BR and A-pg lines
ii to A-Pg (in mm)	Distance of ii from the A-pg line
A6 to PtV (in mm)	Distance of A6 from the PtV line
Additional dentoalveolar and dental variables	
is to NL (mm)	Distance of is from the NL
U1/NL (°)	Angle between is-AR and NL lines
U6 tip to NL (mm)	Distance of U6 from the NL
ii to ML (mm)	Distance of ii from the ML
L1/ML (°)	Angle between ii-BR and ML lines
L6 tip to ML (mm)	Distance of L6 from the ML
Overjet (mm)	Distance between is and ii on OLs
Overbite (mm)	Distance of ii from the OLs

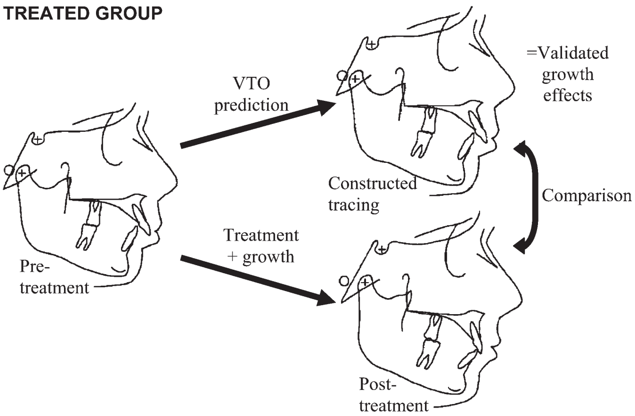

Figure 4 Method used for the evaluation of treatment effects in the treated group. The pre-treatment cephalogram was used to produce a constructed tracing according to visual treatment objective prediction and their differences, resembling the growth effects, were compared with the changes between the pre- and post-treatment cephalogram representing the changes of actual growth and orthodontic treatment. Time period: 2 years.

and the Wilcoxon signed ranks test for non-normally distributed variables were executed for comparison of values between the cephalograms. The significance level was set at $P < 0.01$ in order to compensate for false-positive results from the multiple use of univariate statistical techniques according to Bonferroni correction.

The intra-observer method errors, *S*i, were calculated using the formula: $S_i = \pm\sqrt{\frac{\sum d^2}{2n}}$, where *d* is the difference between the first and second measurement and *n* the number of double registrations (Dahlberg, 1940). Fifteen cases were measured twice by one author (KAP) with a 1 month interval. The values varied between 0.45 and 1.23 degrees for angular and 0.33 and 0.71 mm for linear measurements.

Results

The results of the cephalometric analysis of the untreated control group revealed weak statistically significant differences between the measurements of predicted and true growth (Tables 2a, b). The facial taper angle was greater than estimated. For the dentoalveolar variables, the upper molar was more extruded (U6 tip to NL) in the control group than in the prediction and the lower incisors were more proclined (L1/ML and L1/A-Pg), with the incisal edge more protruded (ii to A-Pg), resulting in a smaller OJ than the estimation. The mean differences between the control and VTO prediction were less than 1 mm or degree except for the divergences in the inclination of the lower incisors.

The results for the treated VAST groups revealed strong statistically significant differences. In the non-extraction subgroup (Tables 3a, b), treatment resulted in a reduction of the facial axis, an increase of the facial taper and lower face height angles, and a reduction of both OJ and OB. The upper first molars were distalized (A6 to PtV), the lower incisors were proclined (L1/A-Pg, L1/ML, ii to A-Pg), and the distance ii to ML decreased due to the inclination, while the lower first molars were extruded (L6 tip to ML).

The findings for the extraction subgroup were similar (Tables 4a, b). The main differences between the extraction and non-extraction subgroups were a non-significant decrease in facial axis and an increased reduction of point A convexity in the extraction group. The upper first molars were mesialized, while in the non-extraction group the upper first molars were distalized.

Discussion

When comparing the pre- and post-treatment lateral cephalograms of a growing individual, the observed skeletal, dentoalveolar, and dental changes are due to the effect of both orthodontic intervention and maturation. For estimating the influence of growth, the use of cephalograms of untreated matched individuals is considered the most appropriate way for establishing a standard for cases with a specific occlusion. However, due to secular trends in growth during the last 50 years (Hunter and Garn, 1969; Smith *et al.*, 1986), the existing material from large growth studies are not considered ideal for comparison of contemporary children and the expected growth increments of older materials are assumed to be small compared with those of the present decades (Proffit and Fields, 2000). This limitation applies also for template methods and should be borne in mind as a possible reason for inaccuracy. The VTO could be a feasible way to overcome secular changes when using the individual facial morphology of a patient as a basis for prediction. However, it should be remembered that the annual growth increments used in the VTO method are independent of age, not being able to estimate the different velocity of growth during childhood.

In order to ensure its validity, the VTO method was tested on a sample of untreated subjects of the same age, gender, ethnicity, and type of occlusion as children treated with the VAST. Additionally, the time periods of growth and growth/treatment were the same for both groups. If VTO was validated for most of the examined variables, the method could be applied on the group of treated patients, in order to evaluate the net treatment effects by subtraction of the predicted changes from the observed changes. In that way, the increase in growth during a specific period of time could be omitted and the true changes due to orthodontic intervention could be revealed.

However, the accuracy of growth prediction for dental variables according to Ricketts' VTO was not investigated by Kocadereli and Telli (1999). As dentoalveolar variables are needed for evaluation of the treatment effects of the VAST, the method used in this study included a test of such variables in Swedish children. Previous investigations of Ricketts' growth prediction (Kocadereli and Telli, 1999) and Ricketts' VTO (growth prediction and treatment effect; Thames *et al.*,

Table 2a Mean values ($\bar{x}$) and standard deviation (SD) for the changes in cephalometric records in the control group (n = 30) during predicted growth and growth for the same time interval. Mean differences ($\bar{d}$) and levels of significance using paired Student's t-test were calculated.

Variable	Prediction		Growth		Difference	Significance
	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{d}$	
Based on Ricketts' 11-factor analysis						
Facial axis (°)	0.1	0.4	−0.4	1.3	−0.4	ns
Facial depth (°)	0.5	0.3	0.9	2.0	0.4	ns
Facial taper (°)	−1.0	0.3	−0.5	1.1	0.6	**
Mandibular plane to FH (°)	0.5	0.3	−0.4	2.4	−0.9	ns
Point A convexity (mm)	−0.4	0.3	−0.3	1.2	0.2	ns
LFH′ angle (°)	0.3	0.4	0.1	1.4	−0.2	ns
L1/A-Pg (°)	1.2	0,7	3.5	5.1	2.3	ns
ii to A-Pg (mm)	0.1	0.2	0.9	1.3	0.7	**
A6 to PtV (mm)	1.7	0.5	1.5	2.2	−0.1	ns
Additional dentoalveolar and dental variables						
is to NL (mm)	0.9	0.6	0.8	1.1	−0.1	ns
U6 tip to NL (mm)	1.2	0.5	1.8	1.1	0.7	**
ii to ML (mm)	0.9	0.3	1.4	1.3	0.4	ns
L1/ML (°)	−0.6	0,5	2.6	4.6	3.1	**
L6 tip to ML (mm)	1.2	0.3	1.2	0.9	0.0	ns
Overbite (mm)	−0.3	0.2	−0.3	1.5	0.0	ns

Table 2b Control group (non-parametric test for two variables). Median, lower (25%), and upper (75%) quartiles for the changes in cephalometric records during predicted growth and growth for the same time interval. Levels of significance using Wilcoxon signed ranks test were calculated (n = 30).

Variable	Prediction			Growth			Significance
	Median	25%	75%	Median	25%	75%	
Additional dentoalveolar and dental variables							
U1/NL (°)	0.1	−0.3	0.7	0.7	−2.4	3.7	ns
Overjet (mm)	−0.1	−0.3	0.1	−0.8	−2.2	0.0	**

ns, not significant; **$P < 0.01$.

1985; Sample *et al.*, 1998; Toepel-Sievers and Fischer-Brandies, 1999) demonstrated moderate precision in predicting the soft tissue changes. Consequently, the soft tissue variable was excluded from Ricketts' 11-factor analysis as inaccurate, as well as measurement of the mandibular arc angle describing the anatomy of the mandible as unsuitable for the evaluation of treatment effects.

As the aim of this study was to evaluate a clinical technique, it was necessary to extend the VTO with recognized dentoalveolar variables. These were expected to change synchronously with the skeletal variable. The results showed mostly non-significant differences for all variables when the validity of the prediction method was tested, and consequently, the variables were also included in the second part when investigating the treatment effects. However, all variables were tested and evaluated in a treated group, during the second part of the investigation, with regard to their accuracy and the error found in the first part.

When testing the growth prediction according to VTO, it was found to be reliable for most of the examined variables in the Swedish material of untreated post-normal individuals, when compared with true growth changes. The main difference was the inclination of the lower incisors, which was underestimated and exhibited various changes as expressed by the high SDs found in the control group. Consequently, the validity of Ricketts' growth prediction mainly for the lower incisors should be accepted with caution. Small inaccuracies were also found for facial taper, indicating less rotation of the mandible, but their mean differences were below 1 mm or degree, close to the method error and being clinically not significant. This is in agreement with previous findings (Thames *et al.*, 1985; Sample *et al.*, 1998; Kocadereli and Telli, 1999; Toepel-Sievers and Fischer-Brandies, 1999) where the VTO growth method was found to correlate with actual growth changes for most skeletal variables, but demonstrated only moderate

Table 3a Effect of the variable anchorage straightwire technique in the treated non-extraction group (n = 16). Mean values ($\bar{x}$) and standard deviation (SD) for the changes in cephalometric variables predicted during growth and treatment, respectively, for the same time interval. Mean differences ($\bar{d}$) and levels of significance calculated using a Student's t-test.

Variable	Prediction		Treatment		Difference	Significance
	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{d}$	
Based on Ricketts' 11-factor analysis						
Facial axis (°)	0.0	0.3	−1.6	1.0	−1.6	***
Facial depth (°)	0.5	0.4	−0.5	1.6	−1.1	ns
Facial taper (°)	−1.2	0.4	−0.2	1.1	1.0	**
Mandibular plane to FH (°)	0.6	0.4	0.7	1.8	0.0	ns
Point A convexity (mm)	−0.3	0.4	−0.7	1.2	−0.5	ns
LFH′ angle (°)	0.4	0.5	2.1	1.6	1.7	**
L1/A-Pg (°)	0.9	0.9	14.8	5.4	13.9	****
ii to A-Pg (mm)	0.0	0.3	3.6	1.7	3.6	***
A6 to PtV (mm)	2.1	0.6	0.2	2.6	−2.0	**
Additional dentoalveolar and dental variables						
is to NL (mm)	0.9	0.7	1.5	1.6	0.6	ns
U6 tip to NL (mm)	1.2	0.6	0.9	1.4	−0.2	ns
ii to ML (mm)	1.3	0.4	−0.6	1.7	−1.9	**
L1/ML (°)	−0.9	0.9	13.5	5.9	14.4	***
L6 tip to ML (mm)	1.2	0.4	3.3	1.4	2.1	***
Overjet (mm)	0.1	0.3	−4.8	2.6	−4.9	***
Overbite (mm)	−0.2	0.2	−3.8	1.3	−3.6	***

Table 3b Treatment effect of variable anchorage straightwire technique in the treated non-extraction group (n = 16: non-parametric test for one variable). Median, lower (25%), and upper (75%) quartiles for the changes in cephalometric records during predicted growth and treatment, respectively, for the same time period. Levels of significance calculated using Wilcoxon signed ranks test.

Variable	Prediction			Treatment			Significance
	Median	25%	75%	Median	25%	75%	
Additional dentoalveolar variable							
U1/NL (°)	0.5	0.0	1.4	−2.7	−6.0	4.9	ns

ns, not significant; ** $P < 0.01$; *** $P < 0.001$.

precision in forecasting dental changes and soft tissue prediction.

The present study showed that growth prediction according to VTO seemed to be valid for a mean period of 2 years and therefore could be used as a reference for investigating the treatment effects of orthodontic intervention. A similar conclusion was reached by Toepel-Sievers and Fischer-Brandies (1999) when they examined the accuracy of VTO for a period of 2–5 years.

Houston (1979) pointed out that when observing an isolated case, a variation of the differences between the predicted and actual values could be noticed due to individual variation in the amount and direction of growth. However, using the mean values from a group, useful information could be provided. In the present study, even if the untreated group differed from the treated groups with respect to some variables, e.g. OB, the VTO method was found to be a valid predictor of growth in an untreated matched control group.

As mentioned in the introduction, the advantage of VAST is the combination of tipping and uprighting tooth movements facilitated by the special type of brackets. This was clearly shown in the treatment effects as the lower incisors were proclined, as a consequence of the elimination of lower arch crowding by sagittal expansion in the non-extraction cases and intruded as expected from the Begg mechanics (Reddy *et al.*, 2000), with early bite opening by intrusion of the anterior teeth. A similar influence from the Begg technique was found in the significant extrusion of the lower first molars.

The proclination of the lower incisors during treatment should be considered minimal, as the prediction method underestimated their inclination. However, especially in the non-extraction group, the lower incisors were excessively proclined and their post-treatment stability is questionable (Little, 1999).

Table 4a Effect of the variable anchorage straightwire technique in the treated extraction group ($n = 13$). Mean values ($\bar{x}$), and standard deviation (SD) for the changes in cephalometric records during predicted growth and treatment respectively for the same time period. Mean differences ($\bar{d}$) and levels of significance calculated using a paired Student's t-test.

Variable	Prediction		Treatment		Difference	Significance
	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{d}$	
Based on Ricketts' 11-factor analysis						
Facial axis (°)	0.1	0.4	−1.1	1.3	−1.2	ns
Facial depth (°)	0.5	0.4	0.1	1.8	−0.4	ns
Facial taper (°)	−1.0	0.6	−0.7	1.1	0.3	ns
Mandibular plane to FH (°)	0.5	0.5	0.6	1.9	0.1	ns
Point A convexity (mm)	−0.3	0.3	−2.3	1.6	−2.0	***
LFH′ angle (°)	0.4	0.4	2.5	0.9	2.1	***
L1/A-Pg (°)	1.2	0.9	11.2	5.2	10.0	***
ii to A-Pg (mm)	0.1	0.3	2.4	2.3	2.3	**
A6 to PtV (mm)	1.9	0.7	3.8	0.9	1.9	***
Additional dentoalveolar variables						
is to NL (mm)	0.9	0.5	1.1	1.2	0.2	ns
U6 tip to NL (mm)	1.1	0.4	2.0	0.8	0.9	***
ii to ML (mm)	1.4	0.4	0.9	1.9	−0.5	ns
L1/ML (°)	−0.5	0.6	7.5	5.9	7.9	***
L6 tip to ML (mm)	1.4	0.4	4.3	0.9	2.9	***
Overjet (mm)	−0.1	0.2	−4.9	1.5	−4.8	***
Overbite (mm)	−0.1	0.2	−3.1	1.5	−2.9	***

Table 4b Treatment effect of the variable anchorage straightwire technique in the treated extraction group ($n = 13$) (non-parametric test for one variable). Median, lower (25%) and upper (75%) quartiles for the changes in cephalometric records during predicted growth and treatment, respectively, for the same time period. Levels of significance were calculated using Wilcoxon signed ranks test.

Variable	Prediction			Treatment			Significance
	Median	25%	75%	Median	25%	75%	
Additional dentoalveolar variables							
U1/NL (°)	0.2	−0.1	0.7	−2.2	−8.2	3.9	ns

ns, not significant; ** $P < 0.01$; *** $P < 0.001$.

The net effects of the VAST after application of VTO showed limited skeletal effects. However, it was found that the mandible moved clockwise together with opening of the bite as a further effect of the influence of the Begg technique. Although some differences were found to be highly statistically significant (e.g. facial axis), these were minimal and perhaps not clinically significant, particularly in the light of the measurement error being of a similar order of magnitude.

In the study of Weichbrodt and Ingervall (1992), on the treatment of Class II division 1 malocclusions using the Begg technique, it was shown that approximately two-thirds of the correction was skeletal with a few dental movements such as retroclined upper and retruded lower incisors. Interestingly, the results in the present study were the opposite with minor skeletal changes when the subtraction of growth increments were considered.

Although every effort was used to minimize proficiency, detection, transfer, and susceptibility biases and retrospective studies are quick, cost effective, and ethically unambiguous according to Livieratos and Johnston (1995), the present investigation cannot achieve the same research design and control of the material as a prospective study. However, by using Ricketts' VTO as a tool for subtracting growth increment during treatment of growing individuals, it was possible to reveal the true effects of orthodontic treatment.

Conclusion

1. The growth prediction method according to Ricketts' VTO was found valid in a sample of Swedish post-normal children, concerning skeletal and dentoalveolar variables.

2. With the VAST, the net treatment effects in post-normal growing patients were achieved mainly by dentoalveolar changes.

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