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Steiner cephalometric analysis: predicted and actual treatment outcome compared

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Structured Abstract

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Objective – To examine the accuracy and precision of the Steiner prediction cephalometric analysis.

Setting and Subjects – The sample consisted of 275 randomly selected patients, treated between 1970 and 1995 at a university department.

Methods – Lateral cephalograms before (T1) and after orthodontic treatment (T2) were analyzed using the Steiner analysis. A prediction of the final outcome at T2 for the variables ANB°, U1 to NA mm, L1 to NB mm, and Pg to NB mm was performed at T1. The difference between the actual outcome at T2 and the Steiner predicted value (SPV), which was done at T1, was calculated. Accuracy (mean difference between T2 and SPV) and precision (standard deviation of the mean prediction discrepancies) of the prediction were studied. Paired *t*-test was used to detect under- or overestimation of the predicted values.

Results – The mean decrease in angle ANB was 1.4 ± 2.7° and for U1 to NA 2.0 ± 2.6 mm, while L1 to NB increased 0.8 ± 2.0 mm and Pg to NB 0.7 ± 1.1 mm. The predicted values for the changes in ANB angle, the distance of upper incisor U1 to NA as well as the distance Pg to NB were significantly overestimated when compared with the actual outcome, while the change in the distance of lower incisor L1 to NB was underestimated.

Conclusion – The prediction of cephalometric treatment outcome as used in the Steiner analysis is not accurate enough to base orthodontic treatment decisions upon.

Key words: cephalometry; orthodontics; prognosis; treatment outcome; validation study

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Introduction

Eighty years ago a method for standardized head radiography was introduced which turned out to be a tremendous advance in the measurement of the growth of the head and face (1). In 1931 Broadbent (2) in the USA and Hofrath (3) in Germany published on the methodology of obtaining standardized cephalometric head films. But it was until 1948 that the first cephalometric analysis in the USA was published by Downs (4), who introduced a practical cephalometric analysis for diagnostic purposes.

Nowadays, analyzing cephalometric radiographs is one of the most commonly used clinical procedures in any orthodontic office. The 2002 JCO study of orthodontic diagnosis and treatment procedures among orthodontists in the USA (response rate 9%), previously conducted in 1986, 1990, and 1996, showed that the most commonly used analysis was the Steiner analysis (in 45.1% of the practices) and its relative popularity as compared to other analyses remained about the same over the years (5). A survey among all orthodontists working in the Netherlands (response rate 78%) showed similar findings. The most commonly used analysis also was the Steiner analysis, used by 58% of the Dutch orthodontists, followed by the Downs analysis that was used by 22% (6). This study also showed that most orthodontists used more than one cephalometric analysis for diagnosis and treatment planning.

The Steiner numerical analysis, which was developed in the 1950s (7–9) suggests a series of measurements not only to diagnose the problem but it also provides guidelines for treatment planning based on the prediction of changes that take place as a result of growth and/or orthodontic therapy. Part of Steiner's analysis concerns the predetermination of the sagittal position of upper and lower incisors based on an estimate for the changes in the ANB angle and the position of the bony chin (Pg) to the line NB at the end of treatment. Once the estimated change in the ANB angle and the Pg-NB distance at the end of treatment have been established the clinician can refer to a set of acceptable compromises for incisor positioning to arrive at the so-called 'resolved' situation. Finally, the treatment goal is individualized as these estimated values must be modified for individuals (9, 10).

Although the Steiner analysis has been used for half a century now no studies could be identified in the literature that have investigated the reliability of the analysis with respect to the estimation of the values as mentioned above. Therefore the aim of this study was to determine the accuracy and precision of the prediction for the changes during treatment in the ANB angle, the Pg-NB distance, and upper and lower incisor position in a large sample of orthodontically treated patients in order to answer the question whether the Steiner prediction analysis is an effective aid in treatment planning.

Subjects and methods

Subjects

The sample of this study was selected from the post-treatment archives of the Department of Orthodontics and Oral Biology, Radboud University of Nijmegen (The Netherlands). This archive contains records of 2368 orthodontically treated patients at least 10 years post-retention. These patients were treated according to a variety of treatment modalities and appliance protocols in the period 1968–1995. The Peer Assessment Rating (PAR) score of all these patients at different follow up stages is available from a previous study (11). For the present study the following inclusion criteria were used:

1. Age at the start of treatment (T1) between 9 and 14 years.
2. Caucasian.
3. Angle Classification Class I and Class II division 1.
4. The presence of satisfactory lateral cephalometric radiographs.
5. Availability of the predictive diagnostic cephalometric analysis at T1 according to Steiner (9).

Patients with craniofacial anomalies, asymmetries or patients, who needed surgical interventions were excluded. The final sample comprised of 275 patients. Table 1 shows the patient distribution according to gender, age, and PAR score at T1 and T2. According to the Angle Classification, the sample consisted of 66 (24%) Class I patients and 209 (76%) Class II division 1 patients.

Methods

The lateral cephalometric radiographs for all treatment stages were taken using the same Cephalostat (Evald

Table 1. **Patient distribution according to gender, age (year. month) and Peer Assessment Rating (PAR) score at T1 (start of treatment) and T2 (end of treatment)**

Gender	n	Age at T1	Age at T2	PAR at T1	PAR at T2
Boys	111	11.7 ± 1.2	14.8 ± 1.4	30.4 ± 10.2	3.9 ± 2.7
Girls	164	11.8 ± 1.2	14.5 ± 1.3	28.6 ± 9.4	3.9 ± 2.6

cephalostat, 120 KV, 10 mA) with the lips in rest position and the teeth in occlusion. The radiographs at T1 were traced and analyzed by different orthodontists according to the Steiner analysis (9). The radiographs at T2 were traced by one observer (RA). Tracings were made using a fine grade acetate paper taped on the radiograph. When the images of the left and the right structures did not coincide with each other, the midpoint between the two was used. The locations of landmarks were indicated by a single fine pencil dot on the tracing. Table 2 gives the landmark and plane definitions and the mode of location. All points were identified with reference to point N. At T1 the anticipated treatment changes were established for the four variables ANB°, U1 to NA mm, L1 to NB mm and Pg to NB mm by the orthodontist, who was treating the patient. The tracings were digitized on a digitizing tablet by one observer (MK). The digitizer was connected to a computer program, which calculated distances and angles in millimeters (mm) and degrees (°), respectively.

To calculate the interobserver agreement at T1 between observer RA and the orthodontists, who treated the patients, RA traced the radiographs of a random sample of 20 patients at T1 too and the tracings were digitized by one observer (MK).

Data analysis

Systematic differences between the observers were tested by the paired *t*-test. Interobserver reliability was expressed as Pearson's correlation coefficients.

The mean and standard deviation for each of the cephalometric variables at T1 and T2 were calculated. Paired *t*-test was used to study changes over time. The mean and standard deviation (at T1 and T2) of the four variables that are used in the Steiner prediction

Table 2. **Point/plane definitions and mode of location**

Points/planes	Definition
N-nasion	The most anterior aspect of the frontonasal suture, located by visual inspection on the tracing
S-sella	Center of the pituitary fossa located by visual inspection on the tracing
A-Point	The deepest point on the contour of the premaxilla, located by fixing the ruler on point N and moving it backwards and forwards until it touches the contour of the premaxilla where A-point is marked
B-Point	The deepest point on the contour of the mandible (mode of location similar to that for A-point)
Pg-pogonion	The most anterior point on the symphysis of the mandible (mode of location similar to that for A-point)
Me-menton	The lowest point on the symphysis of the mandible, located by fixing the ruler on point N and moving it backwards and forwards until the longest distance on the inferior border of the symphysis is found
Go-gonion	A constructed point, located by two tangents, one on the inferior posterior border of the mandible and the other to the posterior border of the ramus. The bisection of these two lines perpendicularly projected on the mandibular corner is point Go
UIA-upper incisor apex	The root apex of the most prominent upper incisor located by visual inspection
LIA-lower incisor apex	The root apex of the most prominent lower incisor located by visual inspection
Ii-incision superius	The incisal tip of the most prominent maxillary incisor, located by visual inspection
Is-incision inferius	The incisal tip of the most prominent mandibular incisor, located by visual inspection
MP-molars point	The mesial contact between the upper and the lower first molars, located by visual inspection
MP	Mandibular plane: a line connected from point Me to point Go
BOP	Bisected occlusal plane: a line connecting the vertical Midpoint, which is estimated visually, between Is and Ii of the maxillary and the mandibular incisors respectively and the mesial contact point between the first maxillary and mandibular molars.

analysis were compared with the mean and standard deviation of the Steiner predicted values (SPV) which were forecasted at the start of treatment.

The accuracy of the SPV was defined as the mean of the prediction discrepancies (T2 − SPV = mean actual outcome minus mean predicted outcome). The precision was defined as the standard deviation of the mean prediction discrepancies as a measure for the variation. Regression analysis was used to determine the influence of the age at T1, gender and Angle classification on the Steiner prediction discrepancy (T2 − SPV).

Next the mean and standard deviation of the four variables at T2 were calculated according to sex and Angle classification. These mean values represent the true biologic outcome values accomplished at T2, which include the average growth and treatment effect with time. Therefore these values could be used as an alternative for the Steiner prediction method to forecast the treatment goal during treatment planning. In this paper this is called the Alternative Prediction Method (Alternative Prediction Values, APV). The accuracy and precision of the Steiner and Alternative prediction method were evaluated by direct comparison of their accuracy (mean) and precision (standard deviations). The accuracy of the Alternative prediction method (T2 − APV) is per definition zero. Differences in accuracy between both methods were tested with the paired *t*-test.

Results

The reliability coefficients for the measurements at (T1) ranged from 0.80 to 0.97. However angle MP to SN had a low reliability (0.5). The measurement error of the angular variables was in the range of 0.8–1.6°. The linear measurements had a measurement error ranging from 0.5 to 1.5 mm.

The mean and standard deviations of the 12 cephalometric measurements at the start of the treatment (T1) and the actual outcome at the end of the treatment (T2) are shown in Table 3. The difference between their mean values was statistically significant except for the measurement Pg & L1 to NB ($p > 0.5$).

In Table 4 the four variables used in the Steiner prediction analysis are presented at T1 and T2, together with the Steiner cephalometric values as predicted at T1 (SPV). From T1 to T2, the ANB-angle and the distance from U1 to NA (mm) were reduced 1.4° and 2.0 mm, respectively. The Steiner prediction, however, expected a greater change of the ANB angle and of the U1 to NA distance. In other words the prediction was too optimistic for these two values. In contrast, the mean value of L1 to NB mm was estimated to be stable. However, L1 to NB mm had been increased 0.8 mm at T2. Therefore, the predicted change in L1 to NB was underestimated by 0.8 mm. The variable Pg to NB was predicted to increase 1.5 mm, but the real change

***Table 3.* Mean values (in mm or degrees) and standard deviations of the 12 cephalometric variables included in the Steiner analysis at the start of treatment (T1) and at the end of treatment (T2) as well as the statistical significance level of the changes over time**

Cephalometric variables	n	T1	T2	*p*-value
SNA°	275	80.0 ± 4.0	79.2 ± 3.6	<0.0005
SNB°	275	75.3 ± 3.7	75.7 ± 3.5	0.003
ANB°	275	5.0 ± 3.1	3.5 ± 1.9	<0.0005
U1 to NA°	275	24.8 ± 6.7	21.8 ± 6.9	<0.0005
L1 to NB°	275	26.1 ± 6.5	27.6 ± 6.5	0.001
Occl to SN°	275	17.4 ± 4.3	15.4 ± 4.5	<0.0005
MP to SN°	275	34.4 ± 5.5	33.3 ± 5.5	<0.0005
U1 to L1°	275	124.6 ± 9.9	126.7 ± 9.2	0.005
U1 to NA (mm)	275	6.6 ± 2.4	4.5 ± 1.8	<0.0005
L1 to NB (mm)	275	5.4 ± 2.2	6.3 ± 2.1	<0.0005
Pg to NB (mm)	275	2.0 ± 1.7	2.6 ± 1.9	<0.0005
Pg & L1 to NB (mm)	275	3.5 ± 3.4	3.6 ± 3.5	NS

T1, at the start of the treatment; T2, at the end of treatment; NS, not significant.

***Table 4.* Mean values (in mm or degrees) and standard deviations of the four cephalometric measurements used in the prediction for 275 patients at the start of treatment (T1), at the end of treatment (T2), and Steiner post-treatment values as predicted at T1 (SPV)**

	T1	SPV	T2	Real change (T2 − T1)
ANB°	5.0 ± 3.1	3.1 ± 1.7	3.5 ± 1.9	−1.4 ± 2.7
U1 to NA (mm)	6.6 ± 2.4	4.0 ± 2.4	4.5 ± 1.8	−2.0 ± 2.6
L1 to NB (mm)	5.4 ± 2.2	5.4 ± 1.8	6.3 ± 2.1	+0.8 ± 2.0
Pg to NB (mm)	2.0 ± 1.7	3.5 ± 1.6	2.6 ± 1.9	+0.7 ± 1.1

T1, at the start of the treatment; SPV, Steiner post-treatment values as predicted at T1; T2, at the end of treatment.

was only 0.7 mm. Therefore, the predicted change was overestimated by 0.8 mm.

Not any significant relationship was found between the prediction error (T2 − SPV) of ANB°, U1 to NA mm, L1 to NB (in mm) with age, sex and Angle classification. The discrepancy for Pg to NB (in mm) showed a statistical significant relation with Angle classification ($p = 0.001$), meaning a larger prediction error in Angle Class II division 1 cases, and sex ($p = 0.03$), showing a larger prediction error in boys.

Table 5 shows the mean and SD of the biologic outcome at T2 according to the Angle classification and gender, which serve as the Alternative predicted cephalometric values for the sample. A comparison of the mean differences between the actual outcome at T2 and the predicted value (T2 − SPV) and between the actual outcome at T2 and the alternative values (T2 − APV) is shown in Table 6. The mean differences T2 − APV are per definition equal to zero. The precision of the Alternative method is of the same magnitude as the Steiner prediction. Only the prediction for Pg to NB shows a substantial improvement of the precision (30%), when using the Steiner prediction analysis.

Table 5. **Mean values (in mm or degrees) and standard deviation (SD) at the end of treatment (T2) of the four cephalometric variables used in the prediction according to Angle Classification and gender**

Cephalometric variables	n	Class I Male	Class I Female	Class II Male	Class II Female
ANB°	275	2.9 ± 1.7	2.5 ± 1.8	3.8 ± 2.1	3.7 ± 2.0
U1 to NA (mm)	275	5.0 ± 1.8	4.9 ± 2.0	4.3 ± 1.7	4.5 ± 1.8
L1 to NB (mm)	275	6.3 ± 1.8	5.8 ± 2.1	6.5 ± 2.3	6.2 ± 2.2
Pg to NB (mm)	275	2.9 ± 1.9	2.8 ± 1.9	2.7 ± 1.8	2.5 ± 2.0

Discussion

In this study the reliability of the Steiner prediction analysis in a sample with Class I and Class II division 1 malocclusions was evaluated. Such a prediction is difficult especially when an estimate of subsequent facial growth has to be included in the prediction. Therefore most of the studies that have been conducted to evaluate the accuracy of predicted treatment results cannot be used to compare with the results of the present study as they were dealing with outcome prediction of orthognathic surgery, where growth plays a minor role (12–16).

Table 1 shows that the patients showed a good treatment result with a reduction of the PAR score of 86%. This means that the results of this study regarding the accuracy and precision of the Steiner prediction analysis were not influenced by the quality of the treatment outcome as all patients had been treated to a good occlusal result.

In the determination of the treatment goal for an individual patient according to the Steiner analysis two steps are critical. First, the clinician has to predict the change in the ANB angle and the Pg-NB distance (in mm) during treatment. This is not easy and requires a sound background in the principles of facial growth and development, as well as insight into possible results that can be achieved with different treatment strategies (17). Furthermore it has been shown that the consistency of orthodontic treatment planning decisions varies markedly between orthodontists (18). Secondly, there is the question of the validity of the acceptable compromises that were proposed by Steiner

Table 6. **Comparison between the Steiner and Alternative method with regard to accuracy and precision**

	Alternative predicted values (T2 − APV) Accuracy (Mean)	Alternative predicted values (T2 − APV) Precision (SD)	Steiner predicted values (T2 − SPV) Accuracy (Mean)	Steiner predicted values (T2 − SPV) Precision (SD)	Improvement in precision (%)
ANB°	0.00	1.93	0.42**	1.70	12
U1 to NA (mm)	0.00	1.78	0.27*	2.29	−22
L1 to NB (mm)	0.00	2.14	0.86**	1.89	12
Pg to NB (mm)	0.00	1.90	−0.85**	1.33	30

%, Improvement of the precision expressed as the percentage reduction in SD when using the Steiner prediction.
Paired *t*-test, significance level: *$p < 0.05$ and **$p < 0.01$.

and described by him as expressing the concept of a normal average American child of average age (8). There is no reference in the literature how and where Steiner derived his mean values, and analyses from (17). Kowalski and Walker (19) studied the generalizability of these norms by applying a mathematical model for the study of craniofacial morphology and growth on a large sample of 'normal' individuals and their incisal angle measurements. They showed that the assumptions inherent in establishing norms for these measurements irrespective of age and sex were tenable. Later on the Steiner cephalometric norms for other populations were also studied and they consistently differed from the Steiner reference values (20–23).

The results of the present study show that the accuracy in forecasting the values of the four variables at the end of active treatment was limited. The predicted change of the ANB angle and the position of the upper incisor to NA (in mm) were overestimated showing that the sagittal correction of the jaw relationship and the upper incisor position were less than expected. In another study, however, it was found that the computer could predict the ANB angle accurately, but in that study the computer overestimated sagittal changes of both points A and B, and therefore angle ANB was not affected (24). In our study the position of the lower incisor to NB was underestimated by 0.9 mm, which means that the lower incisors were more proclined than anticipated at the start of the treatment. This is in agreement with Cangialosi *et al.* (24), who found that the change in L1 to APo was the least accurate prediction and in their study the prediction was also underestimated as compared with the real outcome. Sample *et al.* (25) evaluated the reliability of manual and computer visual treatment objectives by comparing them with the actual treatment results in growing treated patients. They found that both methods were equally accurate when predicting the skeletal changes, and moderately successful in dental and soft tissue forecasting. They concluded that the prediction of the final position of the incisors was always difficult even in non-extraction cases. In our study we also used an alternative method to predict treatment outcome. To this end the mean values at T2, which represent the real outcome, were calculated. When using these values in our sample the precision of this simple method was comparable with the individualized approach in which a careful estimation is made in every individual patient.

Conclusion

The prediction of cephalometric treatment outcome as used in the Steiner analysis is not accurate enough to base orthodontic treatment decisions upon. Strict use and interpretation of the Steiner analysis is questionable, especially as orthodontists often deal with populations different from the sample Steiner used.

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