Original Article

Change of Incisor Inclination Effects on Points A and B

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ABSTRACT

Objective: To identify and evaluate changes in the cephalometric position of points A and B due to an incisal inclination change caused by orthodontic treatment.

Materials and Method: A total of 103 pairs of consecutive pretreatment and posttreatment lateral cephalographs that met the inclusion criteria were systematically collected from the departmental database and digitized using a customized software program (Gela). Repeatability analyses showed good reliability and no evidence of bias. A statistical model was generated using a Generalized Estimating Equation approach to analyze the data accounting for growth and bodily movement because both factors influence the position of points A and B ($P < .001$, $P < .001$). Changes in tooth length were also accounted for, as these changes may influence the calculated position of the centroid ($P = .002$).

Results: Each 10° change in the maxillary incisor inclination results in a statistically significant average change in point A of 0.4 mm in the horizontal plane ($P = .028$). Each 10° change in the mandibular incisor inclination results in a borderline statistically significant average change in point B of 0.3 mm in the horizontal plane ($P = .058$). There were no significant changes in the vertical position of points A and B.

Conclusion: The effects of incisal inclination changes, due to orthodontic treatment, are of no clinical relevance to the position of point A and B, even though they may be statistically significant. The validity of points A and B as skeletal landmarks generally holds true, and accounting for treatment changes is unnecessary. (*Angle Orthod.* 2009;79:462–467.)

KEY WORDS: Cephalometrics; Incisal inclination; Orthodontics

INTRODUCTION

Points A and B are commonly used as skeletal landmarks in cephalometric studies that investigate the efficacy of various treatment modalities on the sagittal relationship between the maxilla and mandible, respectively.[1–6]

Some authors have stated that point A and B are dentoalveolar landmarks that are influenced by growth as well as dentoalveolar remodeling during orthodontic treatment. Thus, changes in the position of points A and B are due to a combination of skeletal and dental changes.[1,7–9] In addition, it is essential that any studies of points A and B should account for growth as well as treatment in an attempt to evaluate the true efficacy of orthodontic appliances on the skeletal bases. Unless all of these factors are accounted for, the validity of studies using points A and B as stable skeletal reference points may be questionable, and this may affect the accuracy of the results.[10]

Few studies have attempted to investigate the effect of incisal tooth movements on the position of points A and B. Cangialosi and Meistrell[7] studied changes associated with palatal root torque of the upper incisor and point A in adolescent patients. They demonstrated a statistically significant correlation between changes in upper incisor root position and point A as they moved posteriorly by 1.7 mm and 3.5 mm, respectively. However, the study did not account for the effect of growth and bodily retraction of the incisors on the position of point A. In addition, the statistical methods used to analyze the data (paired *t*-tests and correlations) did not allow an accurate way of assessing all the data because they do not account for any influ-

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encing variables such as bodily movement, and no indications were given for errors of measurement in the study. Goldin[11] compared the effect of labial root torque on point A in 17 subjects to a matched control group in an attempt to account for growth. He found that labial root torque resulted in an increase in skeletal convexity. However, the data should be observed with some caution as the study mentioned that angular changes were highly variable but failed to express this variability in their data. Erverdi[9] found a direct correlation between incisal inclination change and point A in patients with increased overjet treated with functional or removable appliances. The study used a simple linear regression analysis and found that there was a borderline significance in changes of incisal inclination relative to SN and the position of point A, but the authors did not state the *P* value. The regression analysis suggests that there is 0.16 mm of change in the position of point A in a posterior direction when the tooth proclined by 1°. However, the statistical method of analysis again did not account for growth. Furthermore, there was no mention of a repeatability analysis for measurement errors.

Cephalometric studies are subject to error, and reports often indicate small changes caused by treatment. In some cases, the magnitude of error may approach the therapeutic changes and raise doubt about their validity.[12–14] It is essential that all authors carry out repeatability assessments within a study and consider the effect of measurement variability in the interpretation of the overall results of the study. This is a common fault of cephalometric studies.

The aim of this study was to isolate and evaluate changes in the position of points A and B purely due to incisal inclination changes because of orthodontic treatment. The study accounted for changes at points A and B due to growth and bodily movement of teeth on an individual basis for each subject to ensure as robust an estimate of the outcome as possible.

MATERIALS AND METHOD

The material used in this retrospective cephalometric study consisted of 103 pairs of pretreatment and posttreatment lateral cephalographs of non-syndromic patients who had completed a phase of orthodontic treatment (97 subjects were used in the study; 6 subjects were used twice as they had completed two phases of orthodontic treatment). All radiographs had been taken as part of the standard clinical procedure for diagnosis and treatment of orthodontic patients at the request of the clinician supervising the patient's care.

The inclusion criteria were that radiographs were taken on the same cephalostat (lateral cephalographs were available for each subject both pretreatment and at the end of the orthodontic phase of treatment) and that they were of sufficient quality to allow identification of relevant landmarks.

Ethical approval was granted by the Local Research and Ethics Committee (06/Q0505/54).

The films were selected by consecutively drawing files from the orthodontic department system, and all of those files fulfilling the inclusion criteria listed above were used. Data collection stopped when all the files available on site, from the period 1985 to 2005, had been exhausted.

Cephalometric Analysis

The standardized radiographs were directly digitized and analyzed using a customized computer program (Gela software, written by Gordon Bennet, University of Newcastle, Newcastle, UK). The program prompted digitization of the landmarks in a predetermined sequence. Both films for each subject were traced and digitized side by side. Digitization was undertaken using standardized conditions and was limited to five sets of radiographs per session to minimize error due to operator fatigue.[12] All digitization was carried out by the main author. The identification of landmarks was based on the definitions by Riolo et al[15] for all landmarks except gonion[8] and posterior nasal spine[16] (Table 1).

The Gela program calculated linear measurements in relation to the horizontal reference plane and the vertical reference plane[17] and two angular measurements (upper incisors to the maxillary plane [UI-Mx] and lower incisors relative to the mandibular plane [LI-Md]; Figure 1). The correction factor for magnification of the cephalostat was 0.93, and this was applied to all linear measurements.

A statistical model was used to analyze the data, accounting for changes in the position of points A and B due to growth and bodily tooth movement for each subject on an individual basis. The model was based on the assumption that all changes in the centroid position of the tooth represented changes due to growth and bodily movement at points A and B. Inclination changes of a tooth occur as a result of tipping around the centroid, which is assumed to be independent of changes in inclination.[18] Thus, by identifying changes in the position of the centroid, it is possible to eliminate any changes in the position of points A and B due to bodily movement and to identify the change purely caused by inclination changes.

The centroid is said to be located between 30% and 40% from the apex when the whole length of the tooth is considered.[19] The position will vary depending on the amount of periodontal tooth support. This precise

Table 1. Cephalometric Landmarks, Reference Planes, and Angular Measurements

Landmark, Plane, or Angle	Abbreviation	Definition
Sella	S	Center of the pituitary fossa of the sphenoid bone
Nasion	N	Junction of the frontonasal suture at the most posterior point on the curve at the bridge of the nose
Anterior nasal spine	ANS	Tip of the median, sharp bony process of the maxilla at the lower margin of the anterior nasal opening
Posterior nasal spine	PNS	Point of intersection of the line drawn through the hard palate parallel to the nasal floor and perpendicular from the lowest point of the pterygomaxillary fissure[8]
A point	A	Most posterior point on the curve of the maxilla between the anterior nasal spine and superdentale
B point	B	Most posterior point to a line from infradentale to pogonion on the anterior surface of the symphyseal outline of the mandible
Menton	Me	Most inferior point on the symphyseal outline of the mandible
Gonion	Go	Bisector of the angle between tangent through the posterior margin of the ascending ramus and tangent to the mandibular base at menton[16]
Upper incisor apex	UIA	Incisal apex of the most prominent upper central incisor
Upper incisor edge	UIE	Incisal edge of the most prominent upper central incisor
Lower incisor edge	LIE	Incisal edge of the most prominent lower central incisor
Lower incisor apex	LIA	Incisal apex of the most prominent lower central incisor
Upper incisor axis	UI	Line drawn through UIA and UIE
Lower incisor axis	LI	Line drawn through LIE and LIA
Maxillary plane	Mx	Plane drawn through ANS and PNS
Mandibular plane	Md	Plane drawn through Me and Go
Upper incisor angle	UI-Mx	Upper incisor inclination to maxillary plane
Lower incisor angle	LI-Md	Lower incisor inclination to mandibular plane
Sella-nasion	SN	Plane through sella and nasion
Horizontal reference plane	HRP	Horizontal reference plane was constructed at 7° inferior to SN[17]
Vertical reference plane	VRP	Vertical reference plane was drawn as a perpendicular to HRP at sella[17]

location of the centroid cannot be predicted accurately, and numerous studies using this point have reported different techniques to locate the centroid based on some theoretical assumptions.[20] In this study, the position of the centroid was geometrically determined using the incisal edge and apex coordinates for the maxillary and mandibular incisors. This technique was previously used in other studies.[21,22]

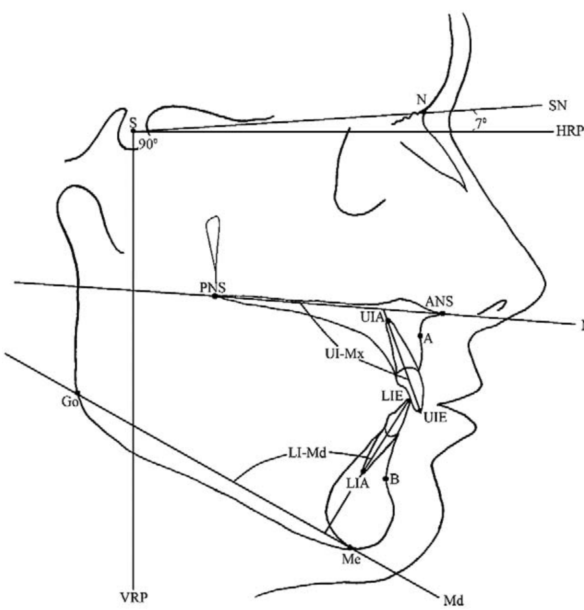

Figure 1. Cephalometric landmarks, reference planes, and angular measurements.

Changes in tooth length due to root resorption were shown to influence the calculated position of the centroid, and this was accounted for by the statistical model.

Overall, the equation used was as follows:

Predicted position of *point A or B* at the end of treatment

$$= \beta_0 + \beta_1 \textit{Pretreatment position of A or B} + \beta_2 \text{change in incisal inclination} + \beta_3 \text{change in centroid} + \beta_4 \text{change in tooth length},$$

where β_0, β_1, β_2, β_3, β_4 are regression coefficients estimated by the statistical model.

A breakdown of how each variable entered in the formula was obtained is described below:

1. The pretreatment position coordinates for points A and B were directly obtained from Gela.
2. The change in incisal inclination was obtained by finding the difference between the pretreatment and posttreatment measurements of UI-Mx and LI-Md for the maxillary and mandibular incisors, respectively.

Table 2. Summary Table for Error of Study Analyses[a]

Variable	Lin's Concordance Correlation ρ_c	Bland and Altman			BSI Coefficient of Repeatability (CR)		Paired *t*-Test
		Mean Diff	SD (Diff)	LOA	CR	*'a priori'* Range	*P* Value
SN	0.989	0.150	0.515	−0.859, 1,159	±1.0	±1.5	.115
ANS v	0.990	−0.075	0.497	−1.048, 0.898	±1.0	±2	.407
A v	0.956	0.000	1.107	−2.170, 2.170	±2.2	±2.5	1.000
UIA v	0.986	0.015	0.695	−1.347, 1.376	±1.4	±2	.905
UIE v	0.993	0.030	0.479	−0.910, 0.969	±1.0	±2	.730
LIE v	0.994	0.060	0.534	−0.986, 1.106	±1.1	±2	.536
LIA v	0.986	0.255	0.804	−1.321, 1.831	±1.6	±2	.088
B v	0.982	0.120	1.247	−2.325, 2.565	±2.5	±3	.596
ANS h	0.988	−0.060	0.748	−1.524, 1.404	±1.5	±2	.658
A h	0.989	0.045	0.661	−1.252, 1.341	±1.3	±2	.708
UIA h	0.993	−0.060	0.573	−1.182, 1.062	±1.1	±2	.564
UIE h	0.994	−0.045	0.694	−1.404, 1.314	±1.4	±2	.720
LIE h	0.995	−0.120	0.689	−1.471, 1.231	±1.4	±2	.340
LIA h	0.990	−0.195	0.996	−2.089, 1.699	±1.9	±2	.270
B h	0.993	−0.015	0.791	−1.567, 1.536	±1.6	±2	.917
UI-Max	0.973	−0.452	1.645	−3.676, 2.772	±3.3	±3	.137
LI-Md	0.977	0.097	1.469	−2.782, 2.975	±2.9	±3	.716

[a] LOA indicates limits of agreement; v, vertical linear measurement from the stated landmark to the horizontal reference plane; h, horizontal linear measurement from the stated landmark to the vertical reference plane. NB units of analysis: linear = mm, angular = degrees.

3. The change in centroid for a given tooth was obtained by finding the arithmetic mean of the (x, y) coordinated for the incisor apex and incisal tip. This value was obtained for the pretreatment and posttreatment cephalographs, and the difference between the coordinates equated to the change in centroid position.
4. Change in tooth length: the long axis of the incisor extends between the coordinates of the incisor apex and tip. This is considered to be the longest side of a right-angled triangle. Its length is calculated using Pythagoras' theorem. The difference between pretreatment and posttreatment lengths provides the change in tooth length.

Statistical analysis of collected data was undertaken using STATA (Intercooled STATA 9.2 © 1985–2005 for Windows, Stata Corp LP, College Station, TX, USA). Data were analyzed using a Generalized Estimating Equations (GEE) approach.[23] This is a form of multiple linear regression analysis that accounts for clustering of the data by generating robust standard errors. This was necessary because six subjects provided data from more than one treatment episode, and thus, the data are not all independent.

Error of the Study

An error study was carried out to measure intra-observer repeatability. Houston[12] recommended that a minimum of 25 cases should be replicated to ensure the detection of a statistically significant systematic error and to avoid the detection of only large errors. Thus, 15% of the sample size was randomly selected from the main series to ensure that the quality of the films used reflected those of the main study. Each radiograph was digitized for the error study 1 week after the original digitization.

Intra-operator repeatability for systematic and random errors was assessed using STATA. The repeatability analyses were paired *t*-tests (for bias), Lin's Concordance Correlation Coefficient (ρ_c), Bland and Altman method, and British Standards Institution (BSI) Coefficient of Repeatability. The results are shown in Table 2. Overall, the study shows good repeatability and no evidence of bias.

RESULTS

The sample consisted of 36 males and 67 females, with a pretreatment age ranging from 8.8 years to 39 years (mean age, 15.1 years; SD, 6 years) and a mean treatment duration of 2.5 years.

The maxillary incisal inclination change ranged from −32.5° retroclination to 25.5° proclination, and the mandibular incisal change ranged from −18° retroclination to 20.5° proclination. The results from the regression analysis using GEE are presented in Table 3.

The results provide evidence that each 10° proclination of the maxillary incisor results in a statistically significant average retraction of point A of 0.4 mm in the horizontal plane, and conversely, each 10° retroclination of the maxillary incisor results in a statistically significant average advancement of point A of 0.4 mm in the horizontal plane ($P = .028$). Each 10° proclina-

Table 3. Results for the Effect of Maxillary and Mandibular Incisal Inclination Changes on Point A and B Position in Horizontal and Vertical Planes When Adjusted for Growth, Bodily Movement, and Tooth Length Changes

Effect of Incisal Inclination Change on:	Coefficient (mm per Degree of Inclination Change)	*P* Value	95% Confidence Interval Lower Limit	95% Confidence Interval Upper Limit
Point A in horizontal plane	−.040	.028	−.075	−.004
Point A in vertical plane	.014	.499	−.027	.056
Point B in horizontal plane	−.031	.058	−.062	−.001
Point B in vertical plane	.000	.997	−.066	.067

tion of the mandibular incisor results in a borderline statistically significant average retraction of point B of 0.3 mm in the horizontal plane, and vice versa ($P = .058$). There was no evidence that incisal inclination changes result in significant changes in the vertical position of points A and B.

The results also confirmed that growth and bodily movement of teeth were statistically significant factors ($P < .001$) in determining the final position of the reference points, as was change in tooth length ($P = .002$).

DISCUSSION

Most of the previous studies have been limited by the fact that a sample size calculation had not been carried out. Although standard software is not readily available to calculate sample sizes using the GEE technique, an attempt was made to overcome this issue in this study by performing a sample size calculation based on the assumption that *t*-tests would be used for the analysis, even though this was not the chosen method for the statistical analysis. This was undertaken on the basis that it was reasonable to assume that the actual power of the study using a GEE approach would be greater than the estimated power of *t*-tests for any given sample size. The approach therefore erred on the side of caution. The sample size calculation was carried out to derive the number of subjects that would give a 90% power of detecting a clinically important change in the sagittal base relationship at the 5% level of significance. The values used for the mean clinical significant change and standard deviation were therefore based on the clinically significant results reported in previous studies that looked at changes in ANB (mean, 1.2°; SD, 1.7° based on a review of previously published studies). The minimum number of subjects required was 48. More subjects than this were used to ensure that the results of this study would be as robust as possible and to provide a high level of precision to the model parameter estimates.

A number of approaches were employed to minimize errors associated with this cephalometric study, including strict adherence to landmark definitions, the use of radiographs of good diagnostic quality, and digitization under standardized conditions using a customized software program. Radiographs were digitized side by side to reduce the error of variance within an individual, although it may increase the risk of bias.[12]

Previous studies that reported errors of their method used Dahlberg's estimation as suggested by Battagel.[13] However, in our opinion, the method used in these studies fails to distinguish between random and systematic errors. The statistical methods used in this study overcame this, and the findings confirmed that there was no evidence of systematic bias and very good agreement. The BSI Coefficient of Repeatability measurements were generally reliable. The only measurement that fell outside the clinically acceptable range of error that was agreed upon (the *'a priori'* range) was UI-Max, and this was only by 0.3°.

Previous studies that attempted to quantify the effect of incisal inclination changes on points A and B had used statistical tests that included paired *t*-tests and univariable linear regression analysis.[9] Those approaches do not account for growth and changes due to bodily retraction of teeth. Results from studies that used Pearson's correlation[7] should also be viewed with caution since those methods similarly do not adjust for other explanatory factors, and the presence of multiple variables will naturally result in correlations being found in biological studies.

In this study, data were analyzed with the aid of a statistical model that addressed the shortcomings of previous studies at a number of levels. It enabled us to account for growth movement on an individual basis, thereby eliminating the need for a matched control group, which would otherwise have been necessary because of the wide age range of subjects in the study as well as the different types of malocclusion. Furthermore, it enabled us to account for changes in the position of points A and B due to bodily retraction of teeth, which has been cited as a factor that may result in dentoalveolar remodeling of point A.[1,7,8]

Generalized Estimating Equations are a form of multiple linear regression analysis and are used to overcome the clustering (non-independence) effect that would have been anticipated because some subjects provided data for more than one course of treatment.

Thus, the changes in the incisor inclination because of orthodontic treatment do not affect the position of point A and B to any clinically relevant extent, as the magnitudes of changes in the skeletal landmarks are very small and irrelevant when they are considered alongside the other errors in cephalometric tracings.

CONCLUSIONS

- Incisal tooth proclination or retroclination because of orthodontic treatment will result in a change in the position of point A and a possible change in point B in the horizontal plane. There is a direct association that can be used to relate one to another.
- Although the results were statistically significant, the magnitude of the change has been found to be clinically irrelevant.
- There is no evidence that changes in incisal inclination affect the position of points A and B in the vertical plane.

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