# A preliminary assessment of cephalometric orthodontic superimposition

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SUMMARY The superimposition of cephalograms is a valuable tool in orthodontics. In children this task is complicated by the fact that growth changes in the reference structures used in superimposition should be taken into consideration. In this study a new method of superimposition of cephalograms taken in the natural head position (NHP) was compared with Viazis' cranial base triangle and a reference grid was used to quantitatively assess the changes in the five selected landmarks. The material consisted of 12 pairs of cephalograms of growing subjects (mean age 11.1 years) collected with a time interval of 1 year.

The results revealed no significant statistical difference between the two methods and both showed high reproducibility. Both analyses were found to be suitable for individual assessment, but the new method involving the use of NHP and easy landmark identification can be considered as a useful addition.

## Introduction

Roentgenographic cephalometry has made a notable impact on clinical orthodontics over the last half century. Since the inception of cephalometrics (Broadbent, 1931), the planning of treatment and the monitoring of change were its inherent potentials. Treatment response and/or growth changes are measured by the superimposition of serial tracings on relatively stable bases or regional contours (Graber, 1994). To monitor change and study cranofacial development longitudinally it is necessary to establish stable reference bases. The majority of research workers have used the sella-nasion line for superimposition at the cranial base (Houston and Lee, 1985). However, nasion, in particular, drifts during growth and remodelling (Houston and Lee, 1985) and, in addition, as nasion is not always readily located in the vertical plane, method errors may arise (Baumrind et al., 1976; McWilliam, 1982).

The specific errors associated with cephalometric superimposition can be attributed to growth and remodelling at the reference plane (Björk, 1969; Björk and Skieller, 1977), as well as to the reproducibility of superimposition on the plane itself (Baumrind *et al.*, 1976; Houston and Lee, 1985). While many new reference bases have been introduced, it is clear that the anterior cranial base region, particularly the cranial surface of the sphenoid bone, displays the greatest stability during growth and remodelling (Brodie, 1953; De Coster, 1953; Steuer, 1972). Although a region's temporal stability is of major concern, the reproducibility or reliability of the methodology is equally important for accurately superimposing serial cephalograms. Most reports do not provide the statistics necessary for

evaluating their technical reliability. Many articles have been published on the relative inaccuracy of different cephalometric superimposition methods (e.g. Baumrind et al., 1976; Houston, 1983; Pancherz and Hansen, 1984; Houston and Lee, 1985; Ghafari and Efstratiadis, 1989), but none of the superimposition methods studied seemed to be superior. Houston and Lee (1985) reviewed five methods of superimposition using cranial structures: the direct superimposition of radiographs (Björk and Skieller. 1983), the superimposition of tracings (Baumrind et al., 1976), the Adams' Blink comparator (Kerr, 1978), a substraction method to register pairs of cephalometric radiographs (Lee, 1980; McWilliam, 1982) and the sella-nasion line of each radiograph. Little or no difference in accuracy between the methods was demonstrated. Recently, You and Hägg (1999) compared the reliability of three commonly employed superimposition methods: Björk's structural, Rickett's four position, and Pancherz's method. Pancherz's method was found suitable to assess changes in orthodontic treatment, but for group rather than individual assessment. Many studies have used the natural head position (NHP) in cephalometric analyses (Siersbæk-Nielsen and Solow, 1982; Cooke and Wei, 1988a; Cooke, 1990; Bass, 1991; Lundström et al., 1991). NHP has been found to be highly reproducible, regardless of age, gender, race, the time between repeated recordings of the radiographic or photographic technique, or the experience or cultural background of the operator (Solow and Tallgren, 1971; Siersbæk-Nielsen and Solow, 1982; Cooke and Wei, 1988b; Cooke, 1990; Bass, 1991; Chiu and Clark, 1991; Lundström et al., 1991; Ferrario et al., 1993). The high interpersonal variability of intracranial reference planes such as the Frankfort plane or sella-nasion line (Solow and Tallgren, 1971; Showfety et al., 1987; Cooke and Wei, 1988b; Michiels and Tourne, 1990) and the need for a holistic approach taking the overall appearance of the patient into consideration (Bass, 1991; Ferrario et al., 1993) led to the evolution of the NHP. NHP has been shown to be correlated to craniofacial morphology (Solow and Tallgren, 1977), future growth trends (Siersbæk-Nielsen and Solow, 1982) and to respiratory needs (Woodside and Linder-Aronson, 1979; Solow et al., 1984). Several researchers have argued that the NHP is the logical reference and orientation position for the evaluation of craniofacial morphology (Moorrees et al., 1976; Foster et al., 1981). In view of all its merits, lateral cephalometric radiographs recorded routinely in NHP would be clinically more meaningful. Several analyses have been recommended for cephalograms taken in NHP, but no reports could be found in the literature of a method of superimposition for this technique.

Viazis (1991) suggested a method of superimposition, the cranial base triangle (CBT), using three points selected within stable structures, thus providing the clinician with a large marking area. However, that method employed intracranial landmarks such as the cribriform plate that are difficult to detect with consistent accuracy.

A technique that reduces the involvement of cranial landmarks may be easier to use and may improve accuracy. This investigation evaluated a new method of cephalometric superimposition that relies to a minimum on cranial landmarks and was especially developed for cephalograms taken in the NHP. To determine the reliability of the results, a reference grid (Pancherz, 1982) was used to assess the changes quantitatively.

## Subjects and methods

The study comprised 12 pairs of lateral cephalograms obtained from students from Bagalkot, India, with a mean age of 11.1 years when the first set of cephalograms was collected. The second set of lateral cephalograms was exposed with a time interval of 374 days by the same examiner (MB) on a Trophy odontorama cephalometric machine (Trophy Radiologie, France), with the settings standardized at 70 Kvp, 6 m-amp for 1.4 seconds. Kodak X-ray films were used and the exposed radiographs were developed and fixed under similar conditions by the same technician to obtain the maximum accuracy. All of the cephalograms were traced manually by a single examiner (MB) directly onto the acetate tracing sheet using a 0.3 mm lead pencil with a back-lit drawing tablet. Only four tracings were carried out at each session to avoid examiner fatigue and error. Each radiograph was traced twice for each method by the same examiner with a time interval of 160-168 hours.

Various methods have been used to record the NHP, such as asking the subject to look at a distant object

on the horizon (Solow and Tallgren, 1971; Lundström, 1982), asking the subject to look into their own eyes in a mirror at the position of greatest comfort (self-balance position; Moorrees and Kean, 1958) and use of a fluid level device (Showfety *et al.*, 1983; Huggare, 1989). In the present study, a combination of the self-balance position and fluid level devices to record NHP was used.

Each subject was asked to relax and the radiographic procedure was explained. A sugar-free cold drink was given to standardize and relax the mental and physical state of the subject, as these may affect posture. Centric occlusion was confirmed using a mouth mirror. Before exposing the cephalogram, each subject was asked to take one step forward and gently nod their head up and down and close their eyes. The fluid level device mounted on the strap was then tied onto the patient's head such that the strap lay 2 mm above the eyebrows in front and behind, exactly at the occipital protuberance. The subject was then asked to open their eyes and look straight into the reflection of their own eyes in a mirror mounted on the wall. The fluid level device was adjusted until the bubble aligned. The procedure was repeated until two readings were obtained. The subject was then asked to sit on the hydraulic chair of the X-ray machine, with care taken so as not to move the subject's head. The ear rods were then lightly engaged and, just before exposure of the radiograph, the reading was again checked. The cephalostat had a plumb line dropped from the ceiling between the tube and the subject to record true vertical.

Viazis' method of superimposition using the CBT is based on three points which define the triangle: T, C and L. The triangle includes the whole anterior wall of sella turcica, as well as the whole of the anterior and middle cranial base. Superimposition on the anterior wall of sella turcica and the stable T–C line, with registration on point T, provides a practical and reliable formation in both the antero-posterior and vertical planes. When the two tracings are superimposed, the bases of the triangle may not fit exactly because of slight remodelling in the area of point L. First priority is given to registration at point T, followed by superimposing on the inner structures of the triangle, and finally on the T–C line.

The new method involved the use of only one intracranial landmark, point T, which lies on the anterior wall of sella turcica and is considered stable after 5 years of age (Björk and Skieller, 1983; Buschang *et al.*, 1986). The two extracranial planes employed were true vertical and true horizontal passing through point T (Figure 1). The two tracings obtained were superimposed on the true horizontal plane registered at point T.

The changes obtained by superimposing the tracings by both methods were assessed using a reference grid (Pancherz, 1982). The grid is established by the occlusal plane with its perpendicular passing through the sella on



**Figure 1** Cephalometric superimposition by the new method. T point: the most superior point of the anterior wall of the sella turcica at the junction with the tuberculum sella.

the cephalogram. On the initial cephalogram, the landmarks to be assessed (in this study: point A, U1, L1, point B and the pogonion) were first determined and the reference grid was marked (Figure 2). The second tracing was then superimposed manually using both methods separately and the reference grid from the initial radiograph was subsequently transferred to the second radiograph. Finally, the position of each landmark was measured along or parallel to the occlusal plane to a line perpendicular to the occlusal plane. The measurements were calculated and the differences in the two superimposition methods were noted. A second set of readings was collected after a time interval of 160–168 hours by the same examiner.

The statistical analysis involved calculating means and standard deviations for each method of superimposition and for each trial. One-way ANOVA was employed to analyse the reproducibility of both of the methods individually and for a comparison of the two techniques. Clinical studies are often concerned with assessing whether different raters/methods produce similar values for measuring a quantitative variable. Use of the concordance correlation coefficient (CCC) as a measure of reproducibility has gained popularity in practice since its introduction (Lin, 1989). Lin's method is applicable for studies evaluating two raters/two methods without replications. In the present study, Lin's CCC was used to assess the reliability of the two superimposition techniques in relation to each of the five landmarks studied. In assessing reliability, means and standard deviations may indicate their systematic error rather than expressing the precision of the repeated measurements. A coefficient



**Figure 2** The skeletal and dental landmarks assessed relative to Pancherz's (1982) reference grid. 1, A (subspinale): the deepest point on the anterior contour of the maxillary alveolar projection determined by a tangent perpendicular to the occlusal line (OL); 2, B (supramentale): the deepest point on the mandibular symphysis between infradentale and pogonion determined by a tangent perpendicular to the OL; 3, Pg (pogonion): the most anterior point on the bony chin determined by a tangent perpendicular to the OL; 4, U1 (upper incisor tip): the incisal tip of the most prominent maxillary central incisor; 5, L1 (lower incisal tip): the incisal tip of the most prominent mandibular central incisor; 6, OL (occlusal line): a line through the incisor tip of the maxillary first permanent molar; 7, OL<sub>p</sub> (occlusal line perpendicular): a line perpendicular to the OL plane through the point S; 8, S (sella): the centre of sella turcica.

of reliability seems to be a better way to assess whether a method is suitable for individual or group assessment (Baughan *et al.*, 1979; You and Hägg, 1999).

#### Results

The reproducibility of the CBT was assessed by comparing two sets of readings on the same cephalograms. The means and standard deviations are presented separately for each landmark of each trial in Table 1. None of the landmarks showed any significant statistical difference. The highest reproducibility was seen for Pogonion and the lowest for point B. The analysis of reproducibility of the same five landmarks with the new method is presented in Table 2. One-way ANOVA failed to detect any significant difference between the two trials for landmark identification. The new method showed reproducibility in relation to these landmarks with the highest rating for L1 and the least for point A.

In the comparison of the two superimposition techniques (Table 3), no significant difference was found between the two methods using one-way ANOVA for any of the landmarks. However, the values calculated using the new method showed the least changes, but the standard deviations were higher than with the CBT method.

Landmark	Trial I		Trial II		F-value*	<i>P</i> -value
	Mean	SD	Mean	SD		
Point A	0.58	1.62	0.42	1.77	0.06	0.81
U1	1.33	2.27	1.46	2.32	0.02	0.89
L1	1.33	2.27	1.17	2.74	0.03	0.87
Point B	1.25	3.31	0.92	3.10	0.06	0.80
Pogonion	1.50	3.83	1.50	3.81	0.00	1.00

 Table 1
 The comparison between two sets of measurements to test the reproducibility of the cranial base triangle.

SD, standard deviation.

\*One-way ANOVA.

P > 0.05 not significant.

Table 2 The comparison between two sets of measurements to test the reproducibility of the new method.

Landmark	Trial I		Trial II		F-value*	P-value
	Mean	SD	Mean	SD		
Point A	0.25	4.09	-0.21	4.21	0.07	0.79
U1	0.50	5.96	0.63	5.89	0.003	0.96
L1	0.42	6.49	0.46	6.91	0.0002	0.99
Point B	0.17	8.32	0.42	8.44	0.005	0.94
Pogonion	0.58	9.78	0.71	9.61	0.001	0.97

SD, standard deviation.

\*One-way ANOVA.

P > 0.05 not significant.

Table 3	The comparison of the two superimposition methods.

Landmark	Method	Mean	SD	F-value*	P-value
Point A	New	0.02	0.05	0.14	0.71
	Viazis	0.50	1.68		
U1	New	0.56	5.92	0.21	0.65
	Viazis	1.40	2.28		
L1	New	0.44	6.69	0.15	0.70
	Viazis	1.25	2.50		
Point B	New	0.29	8.37	0.09	0.76
	Viazis	1.08	3.19		
Pogonion	New	0.65	9.69	0.08	0.78
0	Viazis	1.50	3.80		

SD, standard deviation.

\*One-way ANOVA.

P > 0.05 not significant.

Table 4 shows a comparison of the coefficients of reliability computed using Lin's CCC. Although statistically both methods showed high reliability for the identification of the observed landmarks, there was no statistically significant difference for any of the landmarks. The reliability of the new method was higher than Viazis' method. The coefficient of reliability was highest for pogonion with both methods and least for point A. U1, L1, point B and the pogonion were more reliably reproduced with the new method, while point A showed higher reproducibility with the CBT.

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Landmark	New method	Viazis' method			
Point A	0.90	0.96			
U1	0.99	0.97			
L1	0.99	0.97			
Point B	0.99	0.97			
Pogonion	0.99	0.98			

\*Lin's (1989) concordance correlation coefficient.

## Discussion

The new method investigated uses one intracranial landmark, the point of intersection of the anterior contour of the hypophyseal fossa and the anterior clinoid process. This landmark has long been considered a stable reference point (Björk and Skieller, 1983). Baumrind *et al.* (1976) also reported that the super-imposition of tracings on cranial base structures was more reproducible than using the sella–nasion line. The anterior wall of the sella turcica remains unchanged after 5 years of age (Björk and Skieller, 1983; Buschang *et al.*, 1986). In addition, this structure shows little remodelling, thus enabling easy and precise super-imposition (Melsen, 1974). The new method therefore

employs a useful intracranial landmark for vertical orientation and it provides a reliable landmark to evaluate growth changes in facial structures by superimposition. With the new method, greater reliability is placed on extracranial planes which lend increased credibility to the NHP.

Viazis' method was selected for comparison because the CBT uses the floor and the anterior wall of sella turcica and the midline cranial base structures as far as the anterior limit of the cribriform plate of the ethmoid bone. These structures are known to be the most stable regions of the cranial base (Melsen, 1974). All current cephalometric superimposition methods, except that of Viazis, use structures affected by growth or remodelling (Viazis, 1991).

The main aim of this study was to compare the new method of superimposition of cephalograms taken in the NHP, in growing subjects. In order to evaluate and compare the reliability of both methods, a reference grid (Pancherz, 1982) was used. The grid, although limited in this study to sagittal changes in the selected cephalometric landmarks, eliminated any bias, as it was constructed on the initial radiograph and transferred to the second cephalogram.

The results of the present study show that both methods are reliable (Tables 1 and 2) and no significant differences were found (Table 3). Although the changes measured were numerically small and, with the new method, the standard deviations were large, the statistical analysis based on one-way ANOVA showed that there was no statistically significant difference between the two methods. The magnitudes of the standard deviations reflecting the series of assessments of changes made on individuals were imprecise, and may differ between the two methods. To overcome this problem, Baughan et al. (1979) recommended the use of a coefficient of reliability as a way to assess whether or not a cephalometric measurement is suitable for individual or group assessment. If the coefficient of reliability drops below 0.95, individual assessment becomes very irregular, while if it drops below 0.90, even mean assessment for groups is of little use. The results of this study (Table 4) show that both methods could be employed to assess treatment changes in individuals as well as in groups. Only point A showed less reliability with the new method.

Assessing changes with the new method, the coefficient of reliability was very high (0.99) for dental and skeletal landmarks (Table 4). Although statistically the difference in the reliability coefficient was not significant between the two methods, reliability using the new method was higher except for point A.

The choice of method should be influenced by cost, time and convenience. All of these appear to be superior with the new method. Also the use of NHP to record the cephalograms with their established long-term reproducibility is an additional advantage in the assessment of changes.

The study employed intra-observer reliability, which is less reliable than inter-observer reliability (Hixon, 1956; Stabrun and Danielsen, 1982; Lau *et al.*, 1997). However, Savara *et al.* (1996) reported that the errors are of the same magnitude. A sample comprising only 12 subjects and a time interval of 1 year are some other limitations of the study. Further research is indicated on a larger sample of growing subjects to evaluate long-term changes. A method especially developed for the superimposition of NHP with the involvement of extracranial planes with minimal dependency on intracranial landmarks merits serious consideration for future research.

The results demonstrate that the new method is equally reliable. The high levels of technical reliability demonstrated are in part due to the landmarks used and to some degree of technical experience.

#### Conclusion

A new method for the superimposition of cephalograms taken in the NHP has been presented. Although the study did not prove any statistical superiority between the two superimposition techniques, the new method was found to be as reliable as Viazis' method.

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