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Reliability of different methods for measuring the inclination of the maxillary canines on panoramic radiographs

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Structured Abstract

Objectives – To test the reliability of 4 different methods of measuring maxillary canine inclination (CI) on panoramic radiographs, and to determine whether examiner experience level influenced these measurements under ideal experimental conditions.

Setting and Sample Population – The sample consisted of 20 high-quality panoramic radiographs obtained under standardized conditions using the same radiological apparatus.

Material and Methods – Canine inclination (CI) was measured as either the angle formed by the canine long axis and the midline (method A), a line passing through the suborbitary points (method B), the most superior points of condyles (method C) or the mesiobuccal cusp tip of the first molars (method D). Measurements were made at initial observation (T1) and after 3 months (T2) by 5 experienced orthodontists and 5 undergraduate dental students.

Results – Mean T1-T2 differences for the measurements were close to zero, with no relationship between their magnitude or direction for each method. Intra-rater reliability was excellent, with the lowest values being observed for method B and the highest for method C. No influence of the examiner experience level was detected.

Conclusion – The four methods used in this study to measure CI showed excellent intra-rater and inter-rater reliability, irrespective of examiner experience level. Method B was the least reliable and method C the most reliable, if compared with the others.

Key words: cuspid; mesiodistal inclination; panoramic radiograph; reliability

Introduction

Impaction of the permanent maxillary canine is an important condition in orthodontics because of its frequency (occurring in approximately 2% of the general population and in 4% in the population of patients referred to orthodontists) and because of the possible development of root resorption on the adjacent permanent teeth, which may occur in nearly 50% of cases (1–4). Adequate clinical and radiographic detection of eruption disturbances during the mixed dentition stage allows the clinician to select the management approach that is best suited to reduce the risk of impaction and the associated complications (5–7), because displaced canines have been shown to correct frequently with either early extraction of the deciduous canines (8–11) or concomitant extraction of the deciduous canines and first molars (12, 13).

Together with the mesio-distal location of the cusp tip of the erupting maxillary canine, the inclination of the canine (CI) is an important variable for predicting the risk of impaction or root resorption and the chance of spontaneous eruption after extraction of the deciduous teeth (5, 8, 14–16). Recently, this radiographic indicator has also been used as a pre-treatment predictor of the success rate and duration of surgical-orthodontic treatment of impacted canines (17–19). Traditionally, CI is measured using panoramic radiographs to calculate the internal angle formed by the long axis of the maxillary canine and the dental midline (5, 8, 9). More recently, however, the suborbitary points (20), the most superior points of the condyles (15, 21), and the mesiobuccal cusp tips of the maxillary first molars (22) have also been proposed as landmarks for the construction of a measurement reference line. Although widely used in the literature, the reliability of these methods has not yet been rigorously investigated and compared.

The aim of this study was to assess the reliability of 4 different methods for measuring maxillary CI under ideal experimental conditions, and to determine whether the experience level might influence the measurements.

Material and methods

A descriptive observational study was conducted on 20 panoramic radiographs (mean age of the patients: 9.4 ± 1.3 years) collected from the Department of Orthodontics at the University of Bologna, Italy, after review and approval of the protocol by the institutional review board. The inclusion criteria were the following: 1) fully erupted permanent maxillary incisors and first molars; 2) persistence of the deciduous maxillary canines and molars in the dental arch; 3) intact crowns; 4) no alloy restorations; 5) no fixed orthodontic appliances; 6) high-quality panoramic radiographs with condyles and orbits clearly distinguishable for landmark placement.

All of the panoramic radiographs were obtained using the same device (Pro-Max Orthopantomograph, Planmeca, Helsinki, Finland) under standardized conditions (23). For head positioning, the Frankfort horizontal plane was aligned with the horizontal light guide, the midsagittal plane was aligned with the vertical light guide and the incisal edges of the maxillary and mandibular incisors were placed into the notched bite block. The images were saved in the JPEG format at 600 dpi and imported into AutoCAD (AutoCAD 2008, AutoDesk, Inc., San Rafael, CA, USA), which is a software program that is often used for measurement of angles (24). For the initial observation (T1), each radiograph was separately presented to 5 specialists in orthodontics (experienced examiners) and 5 undergraduate dental students (inexperienced examiners). The principal investigator was aware of the aim of the study and selected each of the examiners from homogeneous groups: the orthodontists had more than 5 years of clinical experience as specialists; the students were attending their fifth year of dental school at the University of Bologna and had already passed the radiology exam. All of the examiners were asked to calculate CI for both the right and left maxillary canines of each radiograph according to the following methods:

- Method A, the internal angle formed by the long axis of the canine and the dental midline

constructed from the perpendicular to the central incisors (Fig. 1) (9);
- Method B, the external angle formed by the long axis of the canine and a straight line passing through both the suborbitary points (Fig. 2) (20);
- Method C, the internal angle formed by the long axis of the canine and a 'bicondylar line' passing through the most superior points of the right and left condyles (Fig. 3) (15); and
- Method D, the external angle formed by the long axis of the canine and a horizontal line passing through the mesiobuccal cusp tip of the right and left maxillary first molars (Fig. 4) (22).

All examiners were previously trained in the use of AutoCAD software and reference lines identification. The radiographs were identified by code and analysed in random order. All images were assessed under standardized conditions at the same examination workplace in a darkened and quiet room. All measurements were performed on a notebook (HP Pavilion, Hewlett-Packard Company, Palo Alto, CA, USA) equipped with a 14 inches LCD monitor at a constant resolution of 1280×800 pixels, a 2.0 GHz Intel Core 2 Duo T7300 processor (Intel, Santa Clara, CA, USA), 2048 Mb of RAM running at 533 MHz and a X3100 Intel Graphics Media Accelerator (GMA). Only the principal investigator was available to check the obtained data for completeness during each measurement session. The long axis of the canines and the reference lines were noted and were subsequently used to establish reference points to calculate the CI values using the angular dimension toolbar of the AutoCAD software. All of the angular measurements were determined in degrees (°), rounded to the nearest 0.01°, and were recorded by the same examiner, who was blind to the aim of the study. The calculation procedure was repeated 3 months after the first observation (T2) to establish differences in the examiner's opinion between the 2 observations. Each examiner carried out 80 measurements for each method and made a total of 320 measurements.

Fig. 1. Inclination of the maxillary permanent canine, measured using method A.

Fig. 2. Inclination of the maxillary permanent canine, measured using method B.

Fig. 3. Inclination of the maxillary permanent canine, measured using method C.

Fig. 4. Inclination of the maxillary permanent canine, measured using method D.

Sample size calculation

A pilot study was conducted on 10 panoramic radiographs: measurements on each canine were carried out twice, on 2 separate occasions spaced 3 months apart, by 1 experienced ortho-

dontist and 1 undergraduate dental student using method A, B, C and D. Within each method, intra-rater agreement was reached if there was a difference $\leq 3°$ between the 2 sessions; inter-rater agreement was reached if there was a difference $\leq 3°$ between the examiners. Intra-rater agreement, as measured by kappa statistic, was equal to 0.8; for inter-rater agreement, about half of the measurements were in agreement. By hypothesizing a kappa value ranging from 0.5 to 0.9 (as derived from the pilot study), with a power of at least 80%, by applying Fleiss formula as modified by Cantor (25), a minimum of 72 measurements was required for each method.

Statistical analysis

The normality of the distributions of the raw data was verified using the Kolmogorov–Smirnov test. Sample means, standard deviations (SD) and coefficients of variation (CV) were calculated. Differences between the angular measurements obtained at T1 and T2 were evaluated using the *t* test for paired data; Pearson's correlation coefficient was also computed for each method between T1 and T2. Agreement between the measurements at T1 and T2 was analysed with Bland–Altman plots using 95% limits of agreement (mean differences ± 1.96 of the SD of the differences) for each method. Intra-rater reliability was examined using Cronbach's alpha and the intraclass correlation coefficient (ICC), whereas inter-rater reliability was tested using the repeated measures analysis of variance (ANOVA) test. A direct comparison between experienced and inexperienced raters was also carried out for each method using ICC.

Statistical analyses were performed using the statistical software SPSS for Windows (version 16.0; SPSS Inc., Chicago, IL). The level of significance was set at 0.05.

Results

The angular measurements relative to the CI were consistent with a Gaussian distribution; thus, they were presented as the means $\pm$ SD (Table 1). Method A showed a higher CV (50.84–51.13%) compared with others (Table 1). There was no statistically significant difference between T1 and T2, with the exception of measurements taken using method C by the group of experienced examiners ($p = 0.031$; Table 1). However, a high and significant Pearson's correlation coefficients were found for this method ($r = 0.99$, $p = 0.0001$). High and significant Pearson's correlation coefficients were found between T1 and T2 for the remaining methods among experienced examiners (0.97 for method A; 0.96 for method B; 0.98 for method D; $p = 0.0001$ for all) and for all the methods among inexperienced examiners (0.96 for method A; 0.95 for method B; 0.98 for method C; 0.97 for method

Table 1. **Comparison of the mean values of canine inclination between T1 (initial observation) and T2 (3 months after the first observation)**

	Orthodontists								Undergraduate dental students							
Method (time point)	A (T1)	A (T2)	B (T1)	B (T2)	C (T1)	C (T2)	D (T1)	D (T2)	A (T1)	A (T2)	B (T1)	B (T2)	C (T1)	C (T2)	D (T1)	D (T2)
Mean (°)	15.25	15.06	105.23	105.07	74.78	74.97	74.92	74.99	15.60	15.54	105.60	105.59	74.40	74.41	74.40	74.46
SD	7.76	7.68	7.61	7.75	7.50	7.58	7.70	7.68	7.93	7.95	7.76	7.83	7.74	7.73	7.88	7.89
CV (%)	50.88	51.06	7.23	7.38	10.03	10.11	10.29	10.24	50.84	51.13	7.35	7.42	10.40	10.39	10.59	10.59
*p****	0.114		0.276		0.031		0.470		0.700		0.949		0.912		0.657	

SD, standard deviation; CV, coefficient of variation.
***Significance of the comparison of the angular measurements between T1 and T2 within each method.

D; $p = 0.0001$ for all). The mean differences for the measurements between T1 and T2 were close to zero for each method. The Bland–Altman 95% limits of agreement were as follows: −0.07 to 0.32° for method A; −0.14 to −0.32° for method B; −0.25 to −0.04° for method C; −0.23 to −0.10° for method D. There also did not appear to be any relationship between the magnitude or direction of the difference in the measurements between T1 and T2 and the average of CI angular values for all the methods (Figs 5 and 6).

The high values of Cronbach's alpha (≥ 0.97) and the ICC (≥ 0.95) indicated an excellent intra-rater reliability within each measurement method, with the lowest values being observed for method B in both groups of examiners and the highest for method C (Table 2). The ANOVA demonstrated that the raters had no significant influence on the results for each method, regardless of their experience level (Table 3). A satisfactory inter-rater reliability emerged from the direct comparison between experienced and inexperienced raters, with ICC being, respectively, 0.98 for method A and method B, 0.99 for method C and method D ($p = 0.0001$ for all).

Discussion

We compared four different methods for measuring CI on panoramic radiographs. The finding of a great relative variability of the measurements for method A (CV varying between 50.84 and 51.13%; Table 1) under these ideal experimental conditions justifies caution in accepting that the dental midline as a reference for measuring CI is fundamentally precise. It should also be acknowledged that, under clinical conditions, variations in imaging parameters and measurement execution may represent an additional source of variability.

No statistically significant differences were detected between the 2 measurement sessions, except for method C (Table 1). The high Pearson's correlation coefficients (all above 0.95) confirmed excellent results for all of the examined methods and also for method C, thereby highlighting the presence of congruity between the 2 measurement sessions. The mean differences between T1 and T2 measurements were nearly zero, with no significant trend to either underestimate or overestimate the angular

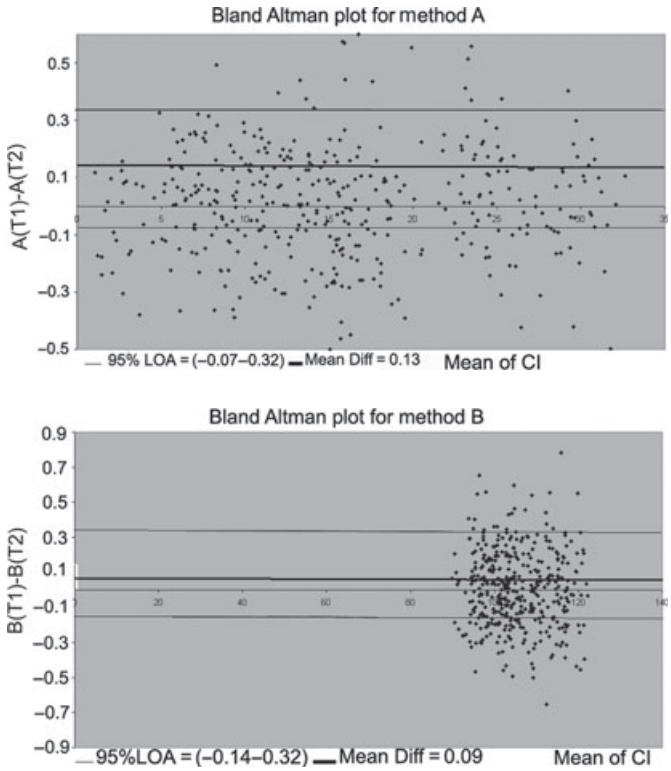

Fig. 5. Bland–Altman plots portraying the agreement between T1 and T2 measurements for method A and B.

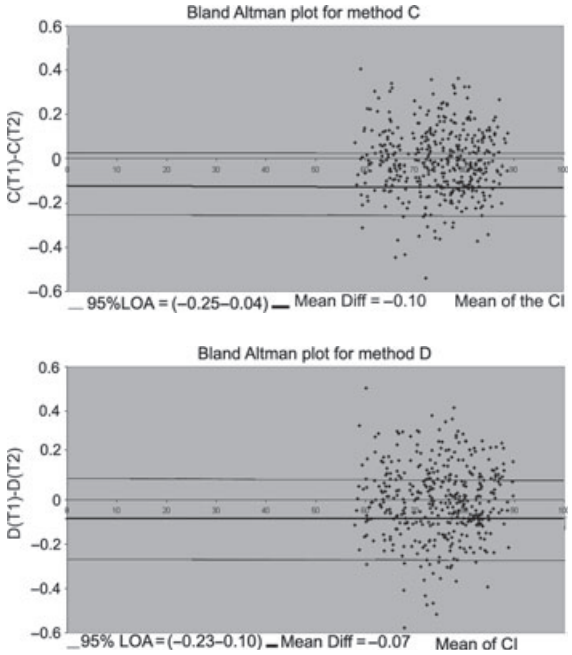

Fig. 6. Bland–Altman plots portraying the agreement between T1 and T2 measurements for method C and D.

values, thereby indicating the presence of harmony and congruity in the examiner's evaluation between the 2 observation sessions (Figs 5 and 6). The Cronbach's alpha (≥ 0.97 for both orthodontists and students) and ICC (≥ 0.95 for both orthodontists and students) values were high, indicating an excellent intra-rater reliability for all of the examined methods (Table 2). When the examiner's clinical experience was assumed as the ANOVA-variable, no inter-rater variance was detected in either group (Table 3). A satisfactory inter-rater reliability, regardless of their experience level, emerged from the direct comparison

Table 2. **Intra-rater reliability analysis ($p = 0.0001$)**

	Orthodontists		Undergraduate dental students	
Method	Cronbach's alpha	ICC	Cronbach's alpha	ICC
A	0.99	0.97	0.98	0.96
B	0.98	0.96	0.97	0.95
C	0.99	0.99	0.99	0.98
D	0.99	0.98	0.99	0.97

between experienced and inexperienced raters, with ICC values all above 0.98. Therefore, it can be speculated that experience in the field of orthodontics is not required to detect canines that are at risk of eruption disturbances and require preventive measures. Not only the orthodontist but also the general practitioner should measure the CI on panoramic radiographs as a reliable means to estimate the degree to which a tooth is likely to become ectopic (15).

As for intra-rater reliability, the lowest values of Cronbach's alpha and ICC were observed for method B, which seemed to be the least reliable of the tested methods. This result might be explained by a greater difficulty in recognizing suborbitary points on panoramic radiographs. The highest values of Cronbach's alpha and ICC were observed for method C. This might be explained by a greater facility in recognizing the most superior points of the condyles on panoramic radiographs. Accordingly, a reference line tangent to these skeletal landmarks has already

Table 3. **Inter-rater agreement analysis (ANOVA)**

	A		B		C		D	
Method	Orthodontists	Undergraduate dental students	Orthodontists	Undergraduate dental students	Orthodontists	Undergraduate dental students	Orthodontists	Under graduate dental students
Sum of squares	10.11	16.30	14.80	12.54	7.28	8.93	1.62	15.96
Mean square	2.53	4.07	3.70	3.14	1.82	2.23	0.41	3.99
F-value	1.73	1.66	1.64	0.99	2.30	1.62	0.35	2.41
p-value	0.14	0.16	0.17	0.42	0.06	0.17	0.84	0.05

been reported to be constant and reproducible (23). The horizontal line passing through the mesiobuccal cusp tip of the right and left maxillary first molars, and the midline also appeared to be reproducible as reference lines for CI; the latter has the advantage of having been widely used and accepted in previous studies throughout the international literature. However, due to the high CV of the measurements relative to the internal angle formed by the long axis of the canine and the midline found in the present study, it is advised to perform duplicate measurements for each canine and average the two values.

Conclusions

The four methods used in the present study to measure CI showed excellent intra-rater and inter-rater reliability, irrespective of examiner experience level. Method B was the least reliable and method C the most reliable, if compared with the others.

Clinical Relevance

The inclination of maxillary canines on panoramic radiographs has been traditionally used as a predictor of the risk of impaction or associated complications, as well as the effectiveness of interceptive approaches to displaced canines. To be of clinical use, it is important to ensure that measurements can be reproduced over time, irrespective of the examiner experience level, so that valid comparisons can be made. This study highlights that 4 different methods available in the literature to measure canine inclination are highly reproducible under ideal experimental conditions.

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