บทวิทยาการ
Original Article

การทดสอบมาตรฐานและความถูกต้องของโปรแกรม สมาร์ท'เอ็น เซฟ ดิจิไทเซอร์ ซอฟท์แวร์ วี 10.0 รีเสริ์ทเชอร์ ในการประเมินการละลายของปลายรากฟัน

Calibration and Validation of the Smart'n Ceph Digitizer Software v 10.0 Researcher for Apical Root Resorption Assessment

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บทคัดย่อ

การเกิดรากฟันละลายจากการรักษาทางทันตกรรมจัดฟันพบได้บ่อย ทั้งๆ ที่เป็นสิ่งไม่พึงประสงค์ของการรักษา การประเมินการละลายของปลายรากฟันที่ถูกต้องแม่นยำและการบ่งชี้ถึงปัจจัยเสี่ยงที่ทำให้เกิดพยาธิสภาพนี้เป็นสิ่งที่มีความสำคัญต่อการรักษาทางคลินิก อย่างไรก็ตามวิธีการในการประเมินการละลายของปลายรากฟันในปัจจุบันต้องเสียเวลามาก โปรแกรม Smart'n Ceph Digitizer Software v 10.0 Researcher (Y&B Products, Chiang Mai, Thailand) ได้ถูกพัฒนาขึ้นร่วมกับภาควิชาทันตกรรมจัดฟัน คณะทันตแพทยศาสตร์ มหาวิทยาลัยเชียงใหม่ เพื่อใช้ในการวัดและประเมินความยาวของฟันบนภาพถ่ายรังสี ซึ่งช่วยทำให้สามารถทำงานได้ง่ายขึ้นและใช้เวลาในการวัดลดลง จุดประสงค์ของการศึกษานี้เพื่อประเมินความแม่นยำของโปรแกรม Smart'n Ceph Digitizer Software v 10.0 Researcher ในการวัดการละลายของปลายรากฟัน เลือกผู้ที่ได้รับการรักษาทางทันตกรรมจัดฟันและพบการละลายของปลาย

Abstract

Apical root resorption resulted from orthodontic treatment is a common, despite undesirable sequel of orthodontic treatment. Therefore, the accurate assessment and identification of factors that predispose this pathology is of clinical importance. However, conventional methods to assess the apical root resorption are time-consuming. The Smart'n Ceph Digitizer Software v 10.0 Researcher (Y&B Products, Chiang Mai, Thailand) was developed in cooperation with the Department of Orthodontics, Chiang Mai University to allow the assessment of apical root resorption on periapical radiographs, thus facilitating measurements. The purpose of this study was to evaluate the accuracy of the Smart'n Ceph Digitizer Software v 10.0 Researcher for apical root resorption assessment. Twenty patients that presented with

รากฟันจากการจัดฟันจำนวน 20 คน วัดความยาวตัวฟันและรากบนภาพถ่ายรังสีปลายรากฟันก่อนและหลังการรักษา แก้ไขความบิดเบี้ยวของภาพ ทำการวัดด้วยมือและด้วยโปรแกรมคอมพิวเตอร์อย่างละสองครั้ง วิเคราะห์ผลแตกต่างทางสถิติของวิธีการวัดด้วยมือและการวัดโดยโปรแกรมคอมพิวเตอร์ โดยวิธี Paired t-test ผลการศึกษาไม่พบความแตกต่างอย่างมีนัยสำคัญทางสถิติระหว่างการวัดทั้งสองวิธี ซึ่งแสดงให้เห็นว่าโปรแกรม Smart'n Ceph digitizer เป็นเครื่องมือที่มีความถูกต้องและสามารถนำมาใช้ในการวัดความยาวฟันได้อย่างแม่นยำและรวดเร็ว โปรแกรมใหม่ที่ได้พัฒนาขึ้นนี้นอกจากจะสามารถนำมาใช้ในการช่วยวินิจฉัยและวางแผนการรักษาทางทันตกรรมจัดฟันแล้วยังสามารถนำมาใช้เป็นเครื่องมือที่มีความไวในการใช้ในงานวิจัยทางคลินิกได้อีกด้วย

คำไขรหัส: คอมพิวเตอร์-ช่วยเหลือ ภาพถ่ายรังสีปลายรากฟัน การละลายของปลายรากฟัน

clearly clinical signs of apical root resorption resulted from orthodontic treatment were selected for this study. Crown and root lengths were measured on pre- and post-treatment periapical radiographs and corrected for image distortion. Manual and computer-assisted measurements were recorded on two occasions. Descriptive statistics were calculated for all measurement differences between the two sets of data from the manual and computer-assisted method. The significance of measurement differences were analyzed using a paired t test. Results showed no statistically significant differences between the manual and the computer-assisted method. This newly developed computer-assisted method shows potential applicability, not only in the clinic as an auxiliary tool for assisting orthodontic diagnosis and treatment planning but also to be used as a high-sensitive tool for clinical research on apical root resorption.

Key words: computer-assisted, periapical radiography, apical root resorption

Introduction

Apical root resorption is a common whereas undesirable sequel of orthodontic treatment that results in permanent loss of tooth structure from the root apex.[1-7] However, factors that are related with the degree of apical root resorption are not clearly understood.[1-5] Frequency of force application,[6] magnitude of the forces applied,[7,8] duration of treatment,[9,10] type of teeth,[11,12] direction of tooth movement,[13,14] and the nature of the supporting bone[15] are the most cited factors.

Methodologies to accurate assess the amount of apical root resorption, thus allowing the identification of factors that predispose a patient to apical root resorption have been the focus of several studies.[16-19] Traditional methods to assess the apical root resorption have been performed in two dimensions with assistance of rulers, protractors and calipers (manual-measurement). However, major limitations to the traditional measuring methods include operator skillfulness in performing measurements accurately, time-consuming and necessity to perform mathematic corrections to allow comparison between

radiographs in case of the radiographic projection and magnification errors.[1,3]

Recently, the use of computer-assisted digitizing software programs has become a commonly applied tool to perform automated measurements in dentistry. However, software programs developed specially to perform measurements of apical root resorption and, incorporate the correction factors for image distortion is limited.

To solve this problem, a custom-made digitizer software program (Smart'n Ceph Digitizer Software v 10.0 Researcher) was developed to allow the assessment of apical root resorption on a periapical radiograph. This computer-assisted measurement method simplifies and reduces the time for measurements when compared with the conventional manual measurement methods. However, the calibration and validation of this developed computer-assisted method remains unclear.

The purpose of this study was to evaluate the accuracy of the newly developed digitizer software for the measurement of apical root resorption following orthodontic treatment and compare the efficiency of this method with the traditional manual measurement methods.

Materials and Methods

Sample

Twenty patients with pairs of pre-treatment (T1) and post-treatment (T2) periapical radiographs of maxillary anterior teeth that presented clearly clinical signs of apical root resorption resulted from orthodontic treatment were selected for this study. All cases were treated with fixed 0.022 x 0.028-inch bracket slots edgewise. The Department of Orthodontics, Faculty of Dentistry, Chiang Mai University supplied the necessary records. All radiographs were made at University using a paralleling long cone technique. The inclusion criteria to for the acquisition of the radiographic material was the absence of abnormal root form at T1 such as; blunt, eroded, pointed, bent or bottle shape.

Examination of periapical radiographs

Crown and root lengths of the maxillary incisors were measured on T1 and T2 periapical radiographs. Tooth length (TL) was measured from the midpoint of the incisal edge to the root apex of maxillary central and lateral incisors. Root width (RW) was measured from the mesial to the distal of the root outlines of the cemento-enamel junction (CEJ). Crown length (CL) was measured from the midpoint of the constructed CEJ line to the midpoint of the incisal edge (Figure 1).

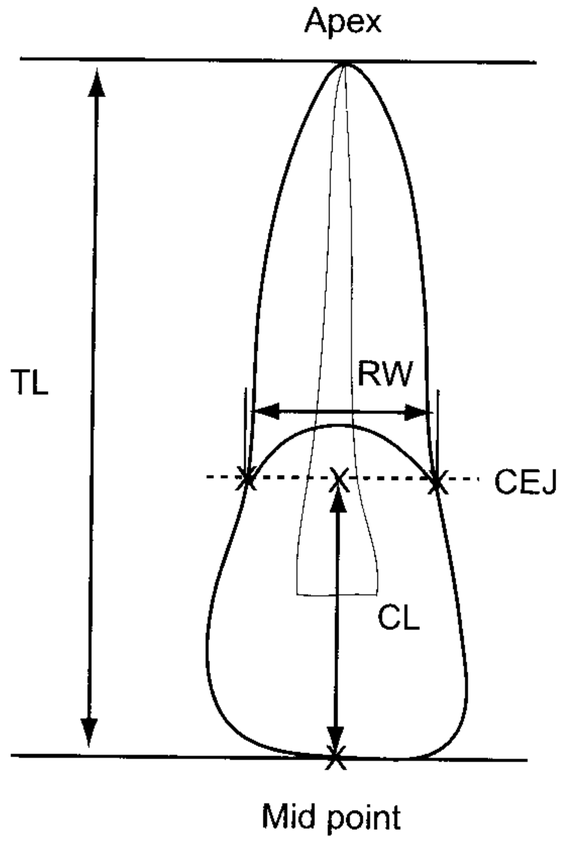

Figure 1 *Diagram showing the reference landmarks used to perform manual and computer-assisted measurement*

Smart'n Ceph Digitizer Software v 10.0 Researcher

The Windows-based Smart'n Ceph Digitizer Software v 10.0 Researcher (Y&B Products LP, Chiang Mai, Thailand) was developed in cooperation with the Department of Orthodontics,

Faculty of Dentistry, Chiang Mai University to allow the measurement of apical root resorption on a periapical radiograph (Figure 2).

All periapical radiographs were converted to digital images using an HP Scanjet 5470c scanner (Hewlett-Packard, Palo Alto, Calif) and a resolution of 300 dpi. Linear measurements are determined by performing movements of the mouse cursor on the digital landmarks created on the computer's screen of an image scanned from periapical radiograph (Figure 3). Pairs of x and y coordinates of the selected points are recorded and automatically calculated by the software. Each pair (T1 and T2) of scanned images were assessed simultaneously on the screen and the most favorable reference points and constructed lines were chosen (Figure 4).

The Smart'n Ceph Digitizer Software v 10.0 Researcher for apical root resorption measurement was used to correct for differences in the enlargement and projections between corresponding images at T1 and T2 to allow accurate comparison. Programmed correction coefficients for image distortion were incorporated to the software using the following equation:

$$\frac{CL1 - CL2}{CL1} = \text{Correction Coefficient (CC)},$$

(CC x TL1) + TL2 = Corrected TL2,

Apical root resorption = Corrected TL2 -TL1,

where CL1 and CL2 is the crown length at T1 and T2, respectively. TL1 and TL1 is the total tooth length at T1 and T2, respectively. CC is the correction coefficient used to adjust the possible distortion observed in T2. Apical root resorption was computed as the difference between the TL2 minus the corrected TL1 (Figure 5).

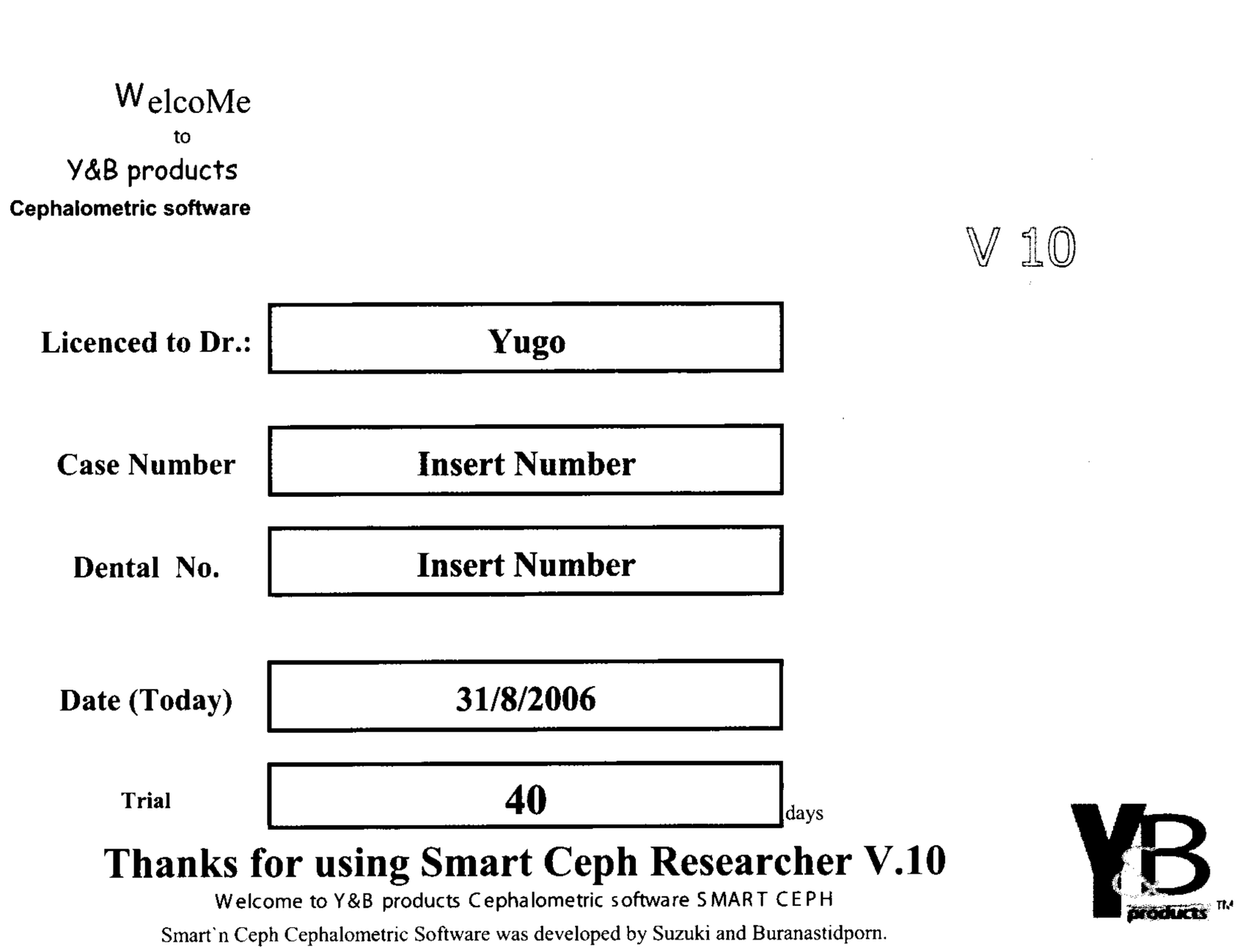

Figure 2 *The main page of the Smart'n Ceph Digitizer Software v 10.0 Researcher. Patient information as well details about the periapical radiographs are recorded for future comparisons.*

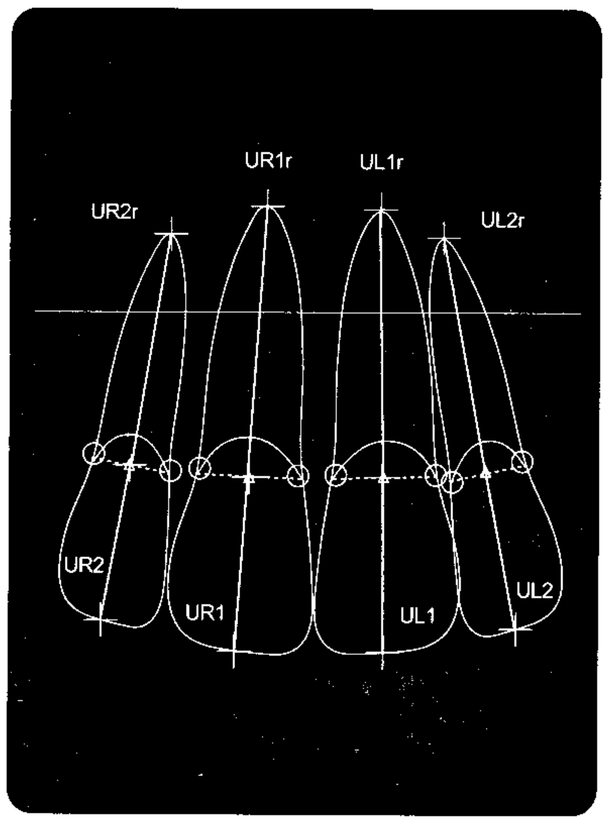

Figure 3 *Simultaneous measurements of apical root resorption of the maxillary anterior incisors can be performed at the plotting area of the Smart'n Ceph Digitizer Software v 10.0 Researcher. UR1 and UR2 stands for the upper right central and lateral incisors, respectively; UL1 and UL2 stands for the upper left central and lateral incisors, respectively; UR1r, UR2r, UL1r and UL2r stands for the apex of the upper right central and lateral incisors and, upper left central and lateral incisors respectively. M stands for the midpoint of the constructed cemento-enamel junction (CEJ) line.*

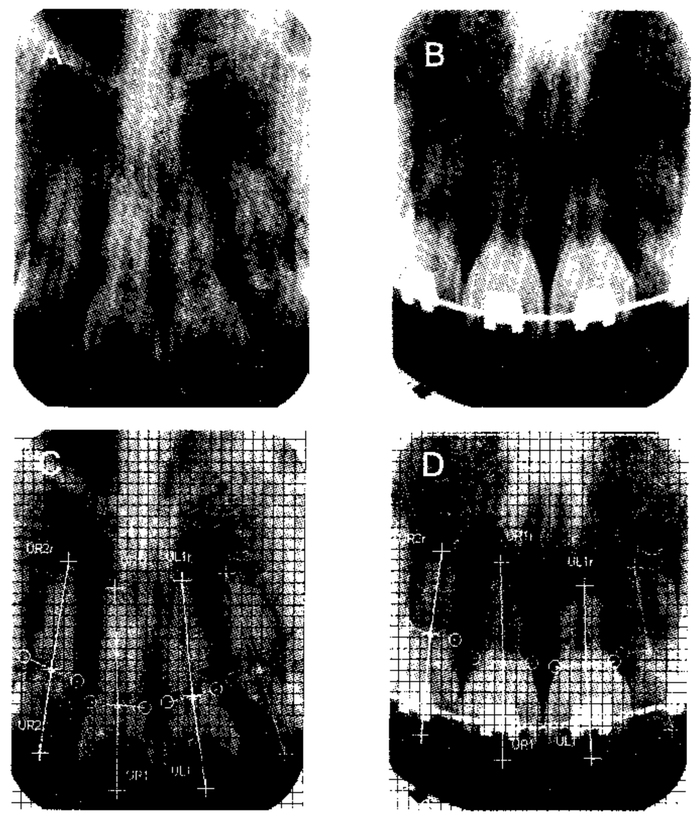

Figure 4 *Periapical radiographs taken with the paralleling long cone technique. A. Periapical film at pre-treatment (T1); B. Periapical film at post-treatment (T2). Note the severe apical root resorption; C. and D, Periapical film at T1 and T2 uploaded to the Smart'n Ceph Digitizer Software v 10.0 Researcher, respectively.*

Manual Measurement

Manual measurements were performed directly on the radiographs directly on the films against a uniformly lit light box with a digital caliper.[7] The caliper was placed along and perpendicular to the pulp canal, respectively. The previous described correction coefficient method for image distortion was used to adjust the possible distortion observed in T2. Root resorption was computed as the difference between the TL2 minus the corrected TL1.

Error of the method

The errors associated with the method were computed using all periapical radiographs in order to examine measurement reliability. Each film was measured and digitized twice, with a three-week interval between the two repetitions. Analysis of the mean differences between duplicate measurements were analyzed using a paired t test to show the systematic errors ($p<0.05$). Dahlberg's method[20] was used to determine the error between the duplicate determinations and the coefficient of reliability was also calculated.[21]

Statistical Analysis

Descriptive statistics (mean and standard deviation) were calculated for all measurement differences between the two sets of data from the manual measurement and those from the computer-assisted method. Apical root resorption was

Smart'n Ceph Digitizer Software v 10.0 Researcher

		Pre		Post	Corrected Post	Correction Factor	Resorption mm	Resorption %
UR2	UR2	17.80	UR2	16.87	14.15	0.84	3.65	36.58%
	UR2r - M	9.97	UR2r - M	7.54	6.33			
	M - UR2	7.83	M - UR2	9.33	7.83			
	UR2 AL	17.80	UR2 AL	16.87	14.15			
UR1	UR1	18.45	UR1	17.99	15.52	0.86	2.93	27.57%
	UR1r - M	10.64	UR1r - M	8.93	7.70			
	M - UR1	7.81	M - UR1	9.55	7.81			
	UR1 AL	18.43	UR1 AL	17.98	15.51			
UL1	UL1	19.03	UL1	15.92	15.41	0.97	3.62	34.37%
	UL1r - M	10.54	UL1r - M	7.15	6.92			
	M - UL1	8.49	M - UL1	8.78	8.49			
	UL1 AL	19.02	UL1 AL	15.92	15.41			
UL2	UL2	17.59	UL2	15.51	15.98	1.03	1.58	16.80%
	UL2r - M	9.38	UL2r - M	7.58	7.81			
	M - UL2	8.18	M - UL2	7.94	8.18			
	UL2 AL	17.55	UL2 AL	15.49	15.96			

Figure 5 *Sample of apical root measurement using Smar'n Ceph Digitizer Software v 10.0 Researcher (results charts). Calculations are used to correct for differences in the enlargement and projections between corresponding images at T1 and T2. Apical root resorption values are calculated in millimeters and percentage.*

calculated by subtracting the corrected value of TL2 from TL1. The significance of measurement differences were analyzed using a paired t test.

Results

The results show that there were no significant differences between the means of the measurements taken on two occasions (Table I).

Using the Dahlberg's calculation method, the mean error for the manual-measurement method was; 0.52 mm (CL1) and 0.62 mm (CL2) for the crown length measurements; 0.45 mm (TL1) and 0.33 mm (TL2) for the crown length measurements; 1.16 mm (RW1) and 1.32 mm (RW2) for the tooth width measurements and 0.55 mm (CC) for the correction coefficient measurements. For the computer-assisted measurement method the mean error was; 0.38 mm (CL1) and 0.42 mm (CL2) for the crown length measurements; 0.57 mm (TL1) and 0.48 mm (TL2) for the crown length measurements; 0.86mm (RW1) and 0.92 mm (RW2) for the tooth width measurements and 0.47 mm (CC) for the correction coefficient measurements.

Using Huston's coefficient of reliability method, the least accurate measurement was the tooth width measurements (RW1 and RW2), while the most reproducible measurements were the total length (TL1 and TL2) measurements for both manual and computer-assisted methods (Table I). In general the crown length (CL) measurements were less reproducible than total length (TL)

Table I Error of the method assessed from duplicate measurement of 20 radiographs

	Variable	Dahlberg's Calculation	Huston's Coefficient of Reliability	Systematic Error: t test (P value)
Manual Measurement	CL1	0.52	99.2	ns
	CL2	0.62	99.7	ns
	TL1	0.45	99.8	ns
	TL2	0.33	99.9	ns
	RW1	1.16	95.6	ns
	RW2	1.32	96.2	ns
	CC	0.56	97.2	ns
Computer-Assisted Measurement	CL1	0.38	98.7	ns
	CL2	0.42	97.9	ns
	TL1	0.57	99.1	ns
	TL2	0.48	99.4	ns
	RW1	0.86	97.6	ns
	RW2	0.92	98.2	ns
	CC	0.47	98.2	ns

CL1=crown length at pre-treatment; CL2=crown length at post-treatment; TL1=total tooth length at pre-treatment; TL2=total tooth length at post-treatment; RW1=root width at pre-treatment; RW2=root width at post-treatment; CC=correction coefficient; **P<0.1

measurements.

The results showed that the measurements differences between the manual and the computer-assisted method were not statistically significant (Table II).

Table II Differences of measurements generated by traditional manual and computer-assisted measurements

Variable	Differences Mean ± SD	t test (P value)
CL1	0.58 ± 0.44	ns
CL2	0.57 ± 0.31	ns
TL1	0.95 ± 0.61	ns
TL2	1.35 ± 1.89	ns
RW1	1.04 ± 0.97	ns
RW2	0.78 ± 0.97	ns
CC	1.32 ± 0.55	ns

CL1=crown length at pre-treatment; CL2=crown length at post-treament; TL1=total tooth length at pre-treatment; TL2= total length at post-treament; RW1=root width at pre-treatment; RW2=root width at post-treatment; CC=correction coefficient;
**P<.01; *P<.05; ns. non-significant

Assessment of apical root resorption was confirmed with both manual (2.58±1.84 mm [mean ±standard deviation]) and computer-assisted measurement method (2.75±1.21 mm). No statistically significant difference was observed between these methods (Table III).

Table III Assessment of apical root resorption using manual and computer-assisted measure-ments methods (n=40)

Variable	Manual Measurement Mean ± SD	Computer-assisted Measurement Mean ± SD	t test (P value)
Apical root resorption (mm)	2.58 ± 1.84	2.75 ± 1.21	ns

n-total number of central incisors; ns. non-significant

Discussion

The accurate assessment of the amount of apical root resorption may contribute to the identification of factors that predispose a patient to this pathology. Methodologies to accurate measure-ment the tooth length using periapical radiographs thus allowing the assessment of degree of external apical root resorption have been the focus of several studies.[1-5] Although the traditional manual-measurement method to assess the dental length in two dimensions with assistance of calipers is considered a gold standard for root resorption assessment, this approach presents limitations. The major disadvantage is the time-consuming procedure to collect the required information from the periapical radiograph. This is particularly important when a large sample number is considered to reduce variability when evaluating several possible factors that might be associated to the apical root resorption.[10] Another disadvantage of manual-measurement is the necessity to perform

additional calculations to correct the radiographic projection and magnification errors, thus allowing comparison between pre-treatment and post-treatment.[3] Recently, the uses of custom-made computer software programs in dentistry field have been commonly applied to allow automated dental length measurements with the advantage of simplifying and reducing the time-consuming procedures. The majority of recent publications investigating the potential factors related to the apical root resorption include relative large samples, consequently, the use of such useful computer-assisted software has became indispensable.

In the present study, custom-made computer-assisted software was developed in cooperation with the Department of Orthodontics, Faculty of Dentistry, Chiang Mai University to allow simple and quick measurements of apical root resorption on periapical radiographs. The Smart`n Ceph Digitizer Software v 10.0 Researcher automate the normally time-consuming and error-prone procedure of dental root length measurement, a critical part of the assessment of the apical root resorption. Moreover, the particular features of the Smart`n Ceph Digitizer Software v 10.0 Researcher allows the automated calculations of correction coefficients for image distortion, such as; differences in the enlargement and projections between series of radiographs, consequently allowing accurate comparison between corresponding images at pre- and post-treatment.

To quantify resorption, pre- and post-treatment periapical radiographs of the upper central incisors, totaling 40 teeth, were examined. The decision to work with only the maxillary central incisors was made because they are the teeth subjected to greater movement during treatment, principally in extraction cases. Additionally, most authors agree that they are more frequently and intensely resorbed during treatment.[7-15]

The results showed that the differences between manual and computer-assisted method of dental length measurements and calculations for the apical dental root resorption were not statistically significant. Consequently, it is possible to conclude that the proposed Smart`n Ceph Digitizer Software v 10.0 Researcher can be used as an accurate tool for allowing precise root length measurements. This newly developed software program also shows potential applicability, not only in the clinic as an auxiliary tool for assisting orthodontic diagnosis and treatment planning but also can be used as a high-sensitive tool for clinical the research.

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