The validity of computer assisted system for lateral cephalometric analysis in comparison with conventional method. II.Onyxceph Imaging Software

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Abstract

Aim: The rapid evolution of digital radiographic systems and digital tracing software is having an impact on cephalometrics, slowly replacing traditional hand-tracing methods on hard copies of radiographic films. The purpose of this study was to examine and compare the reliability and reproducibility of digitization using Onyxceph imaging software (Version 2.6.14) with conventional manual techniques.

Materials and methods: Thirty lateral cephalograms of an office patients previously treated, randomly selected and were evaluated by two methods: manual tracing and indirect digitization using Onyxceph imaging software (Version 2.6.14). Method error (reliability) using duplicate measurements for each method, and comparison of both techniques (reproducibility), were investigated using alternative statistical methods, paired t-test and pearson's Correlation.

Results: All the measurements showed good reliability in both methods except for nasolabial angle in the manual method. Between the two methods, sum of posterior angles measurement had statistically significant difference.

Conclusions: Onyxceph tracing software (version 2.6.14) can be used instead of the time consuming conventional method for lateral cephalometric analysis with good accuracy.

Keywords: Accuracy, conventional cephalometric tracing, cephalometery, software

The most common method to perform cephalometric analysis is by manually placing a sheet of acetate over the cephalometric radiograph, tracing most important features, identifying landmarks, and measuring distances and angles between landmark locations.[1]

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This traditional technique of manually analyzing a cephalometric radiograph is time-consuming and time pressures in the clinical environment can contribute to decreased reliability. [2] The time required for manual analysis depends on how comprehensive the measurements are. Some clinicians make no measurements at all; they hold the radiograph up to the light and get a "clinical impression" of the skeletal and dental pattern of the patient. Other clinicians make extensive, time-consuming measurements, and some clinicians direct a staff member (nonorthodontist) to prepare the analysis. In each case the technique is inefficient, timeconsuming, or prone to error at several steps.[1] Recently numerous computer-assisted methods of cephalometric analysis has been developed. This process requires manual landmark identification and digitization along with computerized measurement of the landmark relationships. The user locates landmarks manually with a mouse cursor on the display monitor on some systems. Other systems digitize landmark locations on a digitizing pad. In either case a computer algorithm performs a cephalometric analysis by calculating distances and angles between landmark locations. In addition, the algorithm connects these landmarks with line segments to produce a tracing. Some systems are capable of moving the tissues to simulate treatment effects, growth effects, and surgical prediction. Finally, some of these systems also are able to produce a time series of images using landmark locations, not superimposition contours, to register images. Digital tracing is either by direct digitization of a previously traced image, or by indirect digitization of the image displayed on the monitor. In both methods, the points are located manually, and so human errors in landmark location remain, and digitization of the traced image actually increases the risk of error. The advantages of digitization include:

-Manipulation of the image (enlargement and enhancement), allowing for more accurate assessment of poorly defined areas (only indirect digitization).

-Speed and choice of analysis.

-Rapid superimposition of serial radiographs.

-Storage and retrieval of multiple records.

-Easy comparison of data in studies. [3]

Although several software programs have been developed for computer-assisted cephalometry,[4,5] the inconsistency observed in the generation of landmarks is a significant source of procedural errors. [6-8] Onyxceph imaging software has a low price amongst other softwares and its use has been common in some faculties of dentistry in Iran. A search of the literature found no research on the accuracy of cephalometric analysis produced by any versions of this Software.

The purpose of this study was to assess the reliability of this imaging software and manual method, and to investigate the reproducibility of software method compared with the manual tracing of the same radiographs.

Materials and Methods

Thirty randomly selected cephalometric radiographs of discharged patients from an orthodontic office with an average age of 11 years and 8 months (range:8.3-14.7 years,11 males and 19 females) were selected, ensuring they fulfilled these criteria:

-Inclusion criteria:

-Patients biting in occlusion.

-Acceptable contrast of hard and soft tissues

-Exclusion criteria

-TMJ disorders

-Cleft lip and/or palate

All of these radiographs were taken by analogue machines. The selected radiographs were of varying qualities and thus ease of landmark identification differed substantially amongst the group. To allow for optimal landmark identification both manually and digitally, all tracings and digitizations were performed in a darkened room and located by the same operator (author).

Manual tracing

Each radiograph was taped to a lightbox (with LED light). A sheet of semi-matt, fine grade acetate paper was then taped over the radiograph, and landmarks were located, using a sharp HB pencil. Twenty one measurements were used as shown in table I. Angular measurements were rounded to the nearest 0.5 using a Perspex protractor (3M UnitekTM Cephalometric Protractor) and linear measurements were measured and rounded to the nearest 0.5 mm using a Perspex ruler.

Digital tracing

The cephalograms were scanned in using a flatbed scanner (HP Scanjet G4050) at 200 DPI, linked to a Dell Computer (Dell WORKSTATION PWS530 running on Microsoft Windows XP). Radiographic images were subsequently imported separately into the software (Onyxceph imaging software, version 2.6.14). The landmarks were identified on a 19-inch colour monitor at a screen resolution of 1280 × 960 pixels via a mouse (cross-hair cursor). For calibration of the images, a known distance of the ruler in the right top of the radiographs was entered in the scale option panel of the sotware. (Figure 1) Manipulation and enhancement was used to assist in point identification when difficulty was encountered. (Figure 2) Since the copy of software used in this study did not have PVL files required for create custom analysis, we selected 4 analysis from the analysis toolbar including Tweed, Tuebingen, Soft tissues and McNamara, then those measurements that automatically were rounded in this software manually recorded and used in subsequent comparative statistics.

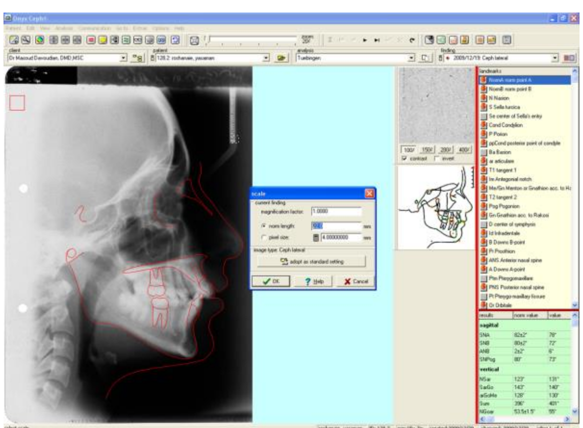

Fig 1: Calibrating of radiograph

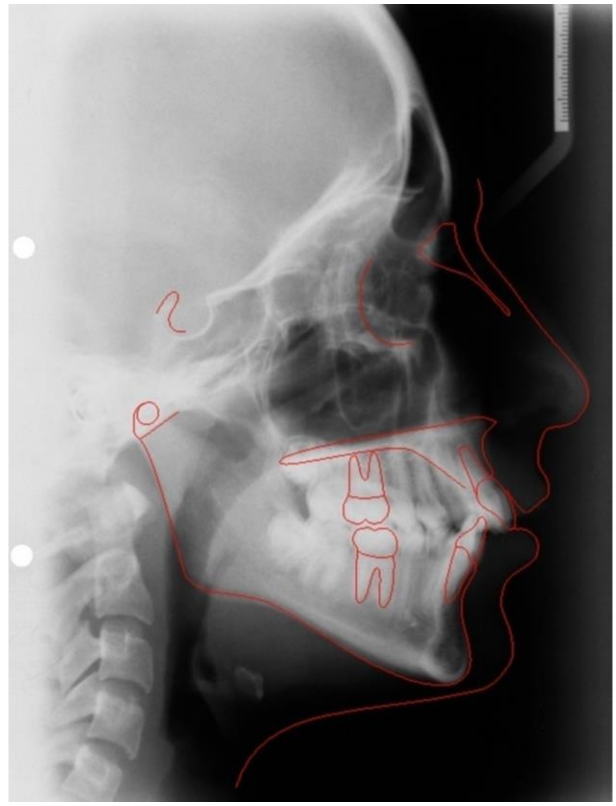

Fig 2: Digitized radiograph

Repeat tracings

In order to determine operator reliability and repeatability, and to establish repeatability of both methods, 15 randomly selected radiographs were retraced for both methods, with a 2 weeks interval between each recording. To avoid any errors that could be encountered in the digital methods when capturing the image, the same saved image was digitized on both the first and second occasions.

Statistical analysis

Examiner error (reliability) was evaluated by duplicating tracings of 15 radiographs (performed a minimum of 2 weeks apart) and using the Pearson correlation coefficient as a measure of standardized covariance.

(Table II) Systematic error (reproducibility) was calculated by paired measurement comparisons of the 30 digital and manual tracings by using paired t- tests based on equality of variance between the 2 samples. A P-value of 0.05 was used as the minimal level of statistical significance (Table III). [6, 9] Accuracy is difficult to ascertain in cephalometrics, much less compare among modes of image capture and measurement techniques. If the manually traced conventional cephalogram is used as a reference, then comparison can be made among the groups so in this study the mean difference between the manual tracings as reference and the digital tracings was determined for each parameter. Because a difference of 2° or 2 mm in means does not appear to cause a clinical difference in classification or treatment decisions in most of the parameters, 6,9,10 any difference less than 2 units was considered to be clinically acceptable.

Table I.selected cephalometric measurements

Measurement	Unit	Definition
SNA	o	Angle between SN and NA
SNB	o	Angle between SN and NB
ANB	o	Angle between NA and NB
Wits	mm	Linear distance between Points A and B parallel to occlusal plane
A-N.perp	mm	Linear distance between Point A and perpendicular line from point N to Frankfort horizontal plane(Po-Or)*
Pg-N.perp	o	Linear distance between Point Pog and perpendicular line from point N to Frankfort horizontal plane
Saddle Angle	o	Angle between SN and NAr
Articular Angle	o	Angle between NAr and ArGo
Gonial Angle	o	Angle between ArGo and MeGo
Sum of posterior Angles	o	Sum of three above angles
PP-MeGo	o	Angle between ANA-PNS and MeGo
SN-MeGo	o	Angle between SN and MeGo
S-Go	mm	Linear distance between Points S and Go
N-Me	mm	Linear distance between Points N and Me
S-Go/N-Me	ratio	Linear distance S-Go over linear distance N-Me
L1-MeGo	o	Angle between Me-Go and line joining crown tip and apex of lower incisor
U1-SN	o	Angle between SN and line joining crown tip and apex of upper incisor
U1-L1	o	Internal angle between upper and lower incisors
Nasolabial Angle	o	Angle between a line tangent to the base of the nose and a line tangent to the upper lip
Upper lip to E plane	mm	Linear distance between Point Ls and Pn'-Pg'
Lower lip to E plane	mm	Linear distance between Point Li and Pn'-Pg'

*For more accurate identification in this study we used Co point instead of Po. [12]

Table II. Differences in duplicate measurements for digital and conventional radiographs (reliablity)

Measurement	Manual method			Digital method		
	Difference		*Coefficient of determination*	*Difference*		*Coefficient of determination*
	Mean	*SD*		*Mean*	*SD*	
SNA	0.00	0.66	0.98	0.13	0.99	0.95
SNB	0.67	0.70	0.98	0.00	1.07	0.95
ANB	-0.07	0.80	0.77	0.27	0.70	0.90
Wits	-0.47	1.30	0.83	0.53	1.30	0.88
A-N.perp	0.47	1.41	0.87	-0.27	2.15	0.72
Pg- N.perp	0.53	3.02	0.87	-0.73	4.37	0.68
Saddle Angle	1.27	3.62	0.79	0.33	1.95	0.93
Articular Angle	-1.53	3.44	0.87	-0.67	1.80	0.95
Gonial Angle	0.33	1.35	0.96	-0.13	1.36	0.95
Sum of posterior Angles	0.07	1.28	0.96	-0.67	1.23	0.98
PP-MeGo	0.07	1.03	0.98	-0.87	1.25	0.97
SN-MeGo	-0.27	0.80	0.98	-0.53	1.06	0.98
S-Go	0.53	1.27	0.72	-0.33	1.80	0.97
N-Me	-0.47	1.06	0.98	-0.80	2.68	0.94
S-Go/N-Me	0.27	1.07	0.87	0.27	0.96	0.98
L1-MeGo	-0.20	1.37	0.96	0.33	3.22	0.82
U1-SN	-0.13	2.07	0.96	-2.00†	2.18	0.96
U1-L1	0.53	2.30	0.96	0.13	4.53	0.88
Nasolabial Angle	-2.8†	6.52	0.28*	0.47	8.09	0.43*
Upper lip to E plane	-0.13	0.52	0.92	0.33	0.98	0.72
Lower lip to E plane	0.07	1.10	0.72	0.53	1.19	0.34*

*Low correlation between repeated measures.

†Differences of mean measurements exceeding 2 units(clinically significant).

Table III. Measurement differences between digital and manual tracings

Measurement	***Difference***		**P** ***value***
	Mean ***(Digital – Manual)***	***SE***	
SNA(°)	0.17	0.99	0.87
SNB(°)	0.23	.980	0.82
ANB(°)	-0.67	.420	0.88
Wits(mm)	-0.90	.920	0.27
A-N.perp(mm)	1.00	0.62	0.88
Pg- N.perp(mm)	-0.27	1.38	0.84
Saddle Angle(°)	-2.23†	1.23	0.12
Articular Angle(°)	0.93	1.46	0.55
Gonial Angle(°)	-1.20	0.59	0.06
Sum of posterior Angles(°)	-2.47†	1.02	0.03*
PP-MeGo(°)	-0.70	0.9	0.44
SN-MeGo(°)	-0.37	1.08	0.75
S-Go(mm)	1.57	1.43	0.22
N-Me(mm)	-0.43	1.3	0.73
S-Go/N-Me(%)	1.67	0.84	0.08
L1-MeGo(°)	-2.97†	1.17	0.10
U1-SN(°)	-1.03	2.07	0.60
U1-L1(°)	2.17†	2.41	0.35
Nasolabial Angle(°)	2.23†	2.4	0.49
Upper lip to E plane(mm)	0.20	0.35	0.60
Lower lip to E plane(mm)	0.40	.50	0.35

*Statistically significant difference between two methods (P<0.05).

†Differences of mean measurements exceeding 2 units (clinically significant).

Results

Table II gives the reliability of repeated measurements by a single operator for the 2 methods investigated. The differences between the means of the 2 samples are also shown. Variability of the differences was reflected in the coefficients of determination (r2) that if more than 0.5, means good reproduction of the variable (good reliability). For manual tracings, the coefficients of determination of all variables were above 0.5 with the exception of nasolabial angle (0.28). For the digital method, we obtained 2 measurements with an r2 below 0.5, including nasolabial angle (0.28) and lower lip to E-line (0.43) although both of them showed mean differences lower than 2 units. In addition, U1-SN had a value equal to 2 units (-2.00) but not statistically significant (0.96). The coefficient of determination for nasolabial angle in manual technique (0.28) was lower than digital method (0.43). Overall, the comparison between r2 values between the two methods showed good reliability and a small error of the operator for all measurements except for nasolabial angle in the manual technique.

Table III gives the measurement differences between the 2 methods. In general, the magnitude of the difference between sample means was small, with only 4 measurements (saddle angle, sum of the posterior angles, L1-MeGo and nasolabial angle) having values above 2 units. Statistically significant difference was detected for the sum of posterior angle measurement.

Discussion

Reliability is an important aspect of a measurement. If a measure cannot be reproduced consistently, then the value (cost, time and patient treatment decisions) of the methodology is questionable. 9 In a clinical situation such as orthodontics, a reproducibility that is within 2° or 2 mm will probably not make a difference in treatment.[6,9] The analysis of the error (Coefficient of determination, Table II) on the conventional tracing showed a high correlation of repeated measures, meaning that the operator had no difficulty in correctly reproducing measurements on traditional procedure and that the landmarks were readily identifiable. Subjective assessment of image quality can predict reliability of landmark location.[13] A low value of the coefficient of determination (0.28) for the nasolabial angle measurement was found in this method. The nasolabial angle is formed by drawing a line tangent to the base of the nose and a line tangent to the upper lip.[12] Since radiographic images used in this research were taken by analogue machines, in spite of try to select better contrast images, however it was possible to have some cases with not enough detectable borderes of soft tissues. Another factor is that the definition of the landmark relates to anatomical variability of the landmark location. A sharp incisal edge would likely have less error associated with its identification than a landmark location associated with a more gradual curve such as Sn point. Errors in the latter would be influenced by the vertical or horizontal orientation of the curve.[14] In addition, based on author experience, drawing the tangent line from Sn point to the base of the nose in manual method is not so accurate and reliable.

Landmark identification is greatly affected by the operator's experience, which might be as important as the tracing method itself. Inter-examiner error has been found in general to be greater than intra-observer error, so that, to minimize errors, all measurements in this study were made by 1 examiner.6 Our data on reliability of hand-traced measurements were similar to those obtained in other studies.[15-17]

Landmark identification from digital images can be affected by several factors such as spatial and contrast resolution of the display device, background luminance level, and luminance range of the display system, brightness uniformity, extraneous light in the reading room, displayed field size, viewing distance, image motion and monitor flickering, signal-to-noise ratio of the displayed image, magnification functions, and user interface.[18] In regard to the digital measurements in our study, reliability was also generally satisfactory, with only the nasolabial angle(0.43) and lower lip to E-line (0.34) having significant mean differences. The same landmark-location difficulties previously discussed for the hand-traced nasolabial angle measurement apply to the digital one, and because the values of the nasolabial angle in digital method statistically and clinically are better than manual method, we can consider the digital, if not perfect, at least equivalent to the manual tracing for this soft tissue angular measurement. The lower lip to E-line value (0.34) was lower than the hand-traced one (0.72). The E-line in our upper lip to E-line measurements did not generate a major reliability problem (r2 = 0.67), so that we could safely assume that locating the labrale inferius(Li) is the major factor in producing the problem. However; the mean difference of this measurement was very small (0.18) and not clinically significant.

U1-SN showed a mean difference even to 2 units but its r2 was statistically acceptable (0.96). Lateral cephalometric radiographs are also used to assess the position of dental structures, most importantly, the position of the maxillary and mandibular incisors. The cephalometric position of the incisors often determines whether the overall treatment plan would involve the extraction of teeth. As a result, the reliability of the landmarks that determine the position of the incisors is of great importance to the treatment planning process itself. Based on Scott et al 14 study on landmark identification error of the four landmarks that define the long axis of the maxillary and mandibular incisors, U1T was reported as the most reliable; in fact, this landmark was identified with the greatest precision of all landmarks, skeletal or dental, for both digital and film-based methods. The distribution of the error at U1T was circular. Therefore, both the precision as well as distribution of the error found at U1T make this landmark an extremely reliable approximation of the incisal tip for measurement purposes and for the construction of the long axis of the maxillary incisor. This determination of U1T as a reliable landmark based on both the precision and distribution of U1T's error is supported by the results reported by Liu and coworkers. [19] UIR, on the other hand, was shown in this study to have identification error beyond the range of precise for the x- and y-axes in film-based identification and for the y-axis alone for the digital identification. The x-axis for the digital identification was, however, shown to be approaching imprecision. The distribution of error that would have the greatest effect on the construction of the long axis of the maxillary incisors would be one along a diagonal descending from right to left, potentially incorporating the greatest amount of error in the determination of the maxillary incisor's inclination. The distribution found at U1R in the Scott et al study 15 was along a diagonal in the opposite direction (descending left to right), a pattern that would result in very little variation in the maxillary incisor inclination. The only effect that an envelope of error in this direction might have is in the estimated length of the maxillary incisor, a variable that is of little concern in cephalometric analysis. The participants in the this study were most likely more concerned with accurately identifying a point along the long axis of the maxillary incisor, rather than identifying the actual root apex of this tooth, resulting in the pattern of error displayed at U1R. This distribution of error will not significantly affect the clinical reliability of the long axis of the maxillary incisor as a cephalometric reference.

Power and coworkers 3 in their study on the accuracy of cephalomtric digitization found that the high mean difference of UIMx

(2.01) and standard deviation of the difference (3.49), as well as the decreased Lin's Concordance Correlation (0.89) and bias correction factor (0.97), indicate lower reliability for this measurement. The upper incisor apex is usually reliably located, [20] although it has been suggested the cursor design may have obscured those peripheral structures that aid in landmark identification, so making visualization more difficult. [21]

Our results indicate that the reliability of repeated measurements appears to be clinically acceptable in both methods except for nasolabial angle in the manual method. Eppley and Sadove [22] reported that, although both digitally enhanced and standard cephalometric radiographs have comparable accuracy for bony landmark identification, digital enhancement is consistently superior at delineating soft-tissue relationships. [23]

Table III reports the results of the comparison, via paired t test, between the digital and the manual method. The statistically significant differences detected just for the sum of posterior angles measurement with a mean difference a little above 2 units (-2.47). Although some other measurements including saddle angle, L1-MeGo and nasolabial angle had above 2 units mean differences, these differences were not statistically significant and were not of a magnitude to be concerned about clinically since they exceeded the cutoff (2 mm or 2°) by only tenths of a millimeter except for L1-MeGo(-2.97).

In our investigation, saddle angle and gonial angle(N.S.Ar) measured by software was smaller than manual method whereas articular angle measured by software was larger than manual method, in balance the sum of posterior angles showed statistically significant smaller magnitude in the digital method. In one report 14 on the accuracy of landmark locating with manual and digital methods, Ar was imprecise in the vertical for film identification and Go in both x- and y-coordinates for both methods. Baumrind and Frantz 20 showed, Go was imprecise along both axes, too. Go point used in Onyxceph imaging software like manual method is determined by constructing the point and using the bisecting angle to a tangent to the posterior border of the ramus and the mandibular plane. Software's calculation of nasolabial angle measurement resulted in measurements near to manual method. In this study nasolabial angle measured in the software similar to manual method by drawing a line tangent to the base of the nose and a line tangent to the upper lip. Other variables that could have influenced landmark identification included the type of registration pointer used in the different software programs. Onyxceph uses a cross hair cursor while some softwares like vistadent (version 7.33 and 8.01) use a conventional pointer that obscured the landmark. Other authors 11,21 related the same difficulties in landmark identification with the cursor obscuring landmarks, so that it can be one reason of good reliability and reproducibility of most of measurements in this study by Onyxceph imaging software.

As technology progresses, it becomes increasingly difficult to determine if there is adequate evidence to assess the efficacy of the technology before it becomes commercially available. Although a multitude of cephalometric analysis software programs have been on the market for several years, there are few studies 4 comparing their reliability and the similarity of measures across the programs. There are also few studies determining if there are differences between different versions of cephalometric analysis software. It can be difficult for the practitioner to select technology that is reliable and accurate unless appropriate studies are available. [11] This study provides a basis for evaluation of the software programs. Further studies in this area will, no doubt, improve our knowledge about the risks and limitations of other softwares. But, for now, the orthodontic office can depend on Onyxceh imaging software(version 2.6.14) for lateral cephalomtric analysis and diagnosis.

Conclusions

1-Both the hand-traced and the digital method can be safely regarded as reliable except for the nasolabial angle measurement in the manual method.

2-When comparing the two methods, the difference between measurements was not statistically significant except for sum of posterior angle measurement with just tenths of a millimeter more than 2 units mean difference.

3-The data suggest that Onyxceph tracing software can be used instead of the time consuming conventional method for lateral cephalometric analysis with good accuracy.

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