The accuracy of computerised cephalometric analysis compared to conventional manual method

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Abstract:

Computerised cephalometric softwares are widely spreading nowadays with several options regarding orthodontists demands. This study aims to compare the accuracy of the computerised procedure from digitising the radiograph to the final cephalometric analysis. Twenty-six lateral cephalograms were analysed, thirteen landmarks were permanently marked and traced and eighteen variables; nine angles and nine lines in both horizontal (X) and vertical (Y) directions were measured manually first, then scanned and the same landmarks were digitised on-screen using Viewbox 3.0.1 cephalometric computer software. The results show that computerised angular measurements were more comparable to the manual method than with linear measurements, with most of the differences being of low clinical importance.

Keywords:

Orthodontic, Computerised cephalometric, on-screen digitisation, digital analysis.

Introduction:

Cephalometric radiographs have been used for many years as part of the records to assist with orthodontic diagnosis and treatment planning. The value of accurate cephalometric analysis in orthodontics and orthognathic surgery is well established.

Until twenty years ago, the method of choice for analysing cephalometric radiographs was manual tracing which then measured with a ruler and protractor.

It is important to distinguish two basic terms: validity and reproducibility. Validity is the extent to which, in the absence of measurement error, the value obtained represents the object of interest. The term accuracy may also be used in this fashion. Reproducibility, or precision, is the closeness of successive measurements of the same object. The term reliability is used as a synonym for reproducibility, but it may also be used in a broader sense to encompass both validity and reproducibility. [1]

However, the relatively recent development of computerised cephalometric software has allowed an increasing number of orthodontists to utilise this technology by digitally recording craniofacial landmarks and permitting the computer programs to calculate the desired measurements.

Various investigators have evaluated the use of computerised cephalometrics and the digitising process of cephalometric radiographs. [2-11]

The cephalometric software market offers at least 20 products and it is extremely difficult to compare

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them because orthodontists have different claims. This study evaluates one of the cephalometric software in comparison to the conventional technique of manual tracing.

Materials and methods:

Twenty-six lateral cephalometric radiographs were selected from the records of the post-graduate clinic at the College of Dentistry, University of Baghdad (19 males, 7 females) with age range 18-25 years. The radiographs were of good quality to provide good scans for the computerised analysis and easy landmark identification. The tracing procedures were performed in two ways:

Manual tracing: the tracing was carried out using a trace foil, 4H 0.5mm mechanical pencil, x-ray light viewer, a tracing template ruler (3M Unitek™) and a protractor (A.W.FABRE). Steiner's analysis was used and thirteen landmarks were permanently marked for each radiograph with pin holes.[12] (Table-1).

Table 1: Landmark definition

Land mark	Definition
A	Point A: The most posterior point on the labial surface of the maxilla between anterior nasal spine and the alveolar process.
ANS	Anterior Nasal Spine: The anterior tip of the nasal spine at the lower margin of the anterior nasal opening
Ar	Articulare: The point of intersection of the posterior margin of the ascending ramus and the outer margin of cranial base.
B	Point B: The most posterior point in the outer contour of the mandibular alveolar process in the median plane.
Go	Gonion: The constructed point where the ramus plane and mandibular plane intersect.
LIA	Lower Incisor Apex: Root apex of the most anterior mandibular central incisor.
LIE	Lower Incisor Edge: The tip of the most anterior mandibular central incisor.
Me	Menton: The most inferior point symphyseal outline of the mandible.
N	Nasion: the most posterior point of the nasofrontal suture in the median plane.
PNS	Posterior Nasal Spine: the intersection of the continuation of the anterior wall of the pterygopalatine fossa and the floor of the nose.
S	Sella: The midpoint of the hypophyseal fossa.
UIA	Upper Incisor Apex: Root apex of the most anterior maxillary central incisor.
UIE	Upper Incisor Edge: The tip of the most anterior maxillary central incisor.

From these landmarks, eighteen variables were calculated; nine angles and nine linear measurements in both horizontal (X) and vertical (Y) directions (Table-2).

Table 2 Variable definitions

Variable	Unit	Definition
ANB angle	Degree	Angle between N-A and N-B
Anterior cranial base	Millimetre	Distance between S and N
Anterior face height	Millimetre	Distance between N and Me
Articular angle	Degree	Angle between S-Ar and Ar-Go
Gonion angle	Degree	Angle between Ar-Go and Go-Me
Inter-incisal angle	Degree	Angle between UIA-UIE and LIA-LIE
Lower anterior facial height	Millimetre	Distance between ANS and Me
Lower incisor to Go-Me	Degree	Angle between LIA-LIE and Go-Me
Mandibular body	Millimetre	Distance between Go and Me
Maxillary length anterior	Millimetre	Distance between ANS and PNS
Posterior cranial base	Millimetre	Distance between S and Ar
Posterior face height	Millimetre	Distance between S and Go
Ramus height	Millimetre	Distance between Ar and Go
Saddle angle	Degree	Angle between N-S and S-Ar
SNA angle	Degree	Angle between S-N and N-A
SNB angle	Degree	Angle between S-N and N-B
Upper anterior facial height	Millimetre	Distance between N and ANS
Upper incisor to palatal plane	Degree	Angle between ANS-PNS and UIA-UIE

Computerised tracing: the radiographs were all scanned with Genius ColorPage 6HRX Slim scanner at a resolution of 150 dpi (dot per inch) (the default setting of the tracing computer software) using a 1.1GHz Intel™ Celeron™ personal computer.

The ruler that was used in the measurements was scanned with the radiograph. The resultant pictures were stored in a JPEG format with a compression ratio of 5.3. The pictures were imported into cephalometric computer software (Viewbox version 3.0.1.5). (Figure 1).

Figure (1): Viewbox software

Various enhancements features provided by the software were freely allowed to use such as magnifying the pictures, changing brightness, contrast, and other advanced picture processing tools in order to allow for the best digitising of the pre-marked landmarks. Digitising was carried out on-screen using the mouse for all thirteen marked landmarks; the program also provided a tool for correction of magnification of the radiograph, so magnification due to scanning was corrected on the ruler that was scanned with the radiograph to eliminate the chances for changes in the size of the scanned radiograph. The program was set to calculate all of the eighteen variables that were included in the study. The results of measurements were exported to Microsoft Excel XP™ spreadsheet program. Statistical analysis was carried out using t-test with enequal variances using Microsoft Excel XP™ data analysis tool pack.

Results

Tables 3 and 4 show the means, standard deviations, minimum and maximum readings for angular and linear measurements respectively. The highest standard deviations are found in both digital and manual inter-incisal angle for angular measurement (8.373 for digital and 8.390 for manual), and anterior face height (N-Me) for linear measurement (6.848 for digital and 6.777 for manual).

Table 3: Means and standard deviations for angular measurements. (in degrees)

Variable	Analysis	Mean	SD	Min	Max
Saddle angle (N-S-Ar) angle	digital	128.165	6.446	118.7	142.3
	manual	128.154	6.280	119	142.5
Articular angle (S-Ar-Go) angle	digital	139.862	5.442	126.7	146.9
	manual	139.885	5.318	127	147
Gonial angle (Ar-Go-Me) angle	digital	125.796	5.477	114.8	135.6
	manual	125.904	5.550	115	136
SNA angle	digital	79.796	4.813	69.7	88.2
	manual	80.058	4.863	70	88.5
SNB angle	digital	77.569	4.576	66.4	84.4
	manual	77.885	4.655	67	85
ANB angle	digital	2.227	1.972	-1.7	6.4
	manual	2.173	1.959	-2	6.5
Upper Incisor- Palatal angle	digital	115.188	6.256	96.7	125.8
	manual	115.327	6.202	97	126
Lower Incisor to Go-Me angle	digital	95.473	6.250	87.4	114.1
	manual	94.981	6.177	87	113.5
Inter-incisal angle	digital	125.427	8.333	108	140.4
	manual	125.538	8.390	108.5	141

Table (4): Means and standard deviations for linear measurements.

Variable	Analysis	Mean	SD	Min	Max
Anterior cranial base(S-N)(mm)	digital	80.158	3.857	73.4	88.3
	manual	79.808	3.878	73	88
Maxillary length anterior (mm)	digital	55.062	3.542	48.6	62.2
	manual	54.673	3.518	48	62
Mandibular body (Go-Me)(mm)	digital	80.738	6.089	65.5	92.4
	manual	80.500	6.129	65	92
Posterior cranial base(S-Ar)(mm)	digital	41.231	3.510	34.7	48.6
	manual	41.038	3.580	34	49
Ramus height (Ar-Go) (mm)	digital	58.138	5.249	49.7	72.5
	manual	57.942	5.399	49	73
Posterior face height(S-Go)(mm)	digital	93.404	6.668	78.2	106.4
	manual	93.481	6.734	78	106.5
Upper Anterior Facial Height(mm)	digital	62.650	3.146	54.9	68.7
	manual	62.596	3.076	55	69
Lower Anterior Facial Height(mm)	digital	78.362	5.932	66.2	91.1
	manual	78.423	6.041	66	91
Anterior face height(N-Me)(mm)	digital	139.819	6.848	131.1	158.9
	manual	140.077	6.777	131	159

Table 5 compares between both manual and computerised (digital) angular measurements. No significant differences have been found between the two methods for all the variables.

Table (5):Comparison between manual and digital angular measurements($p<0.05$)

Angular measurements	Method	Mean	Variance	P-value	Significance
Saddle angle (N-S-Ar)	computer	128.165	41.556	0.995	not significant
	manual	128.154	39.435		
Articular angle (S-Ar-Go)	computer	139.862	29.612	0.988	not significant
	manual	139.885	28.286		
Gonial angle (Ar-Go-Me)	computer	125.796	29.993	0.944	not significant
	manual	125.904	30.800		
SNA angle	computer	79.796	23.160	0.846	not significant
	manual	80.058	23.647		
SNB angle	computer	77.569	20.938	0.806	not significant
	manual	77.885	21.666		
ANB angle	computer	2.227	3.888	0.922	not significant
	manual	2.173	3.839		
Upper Incisor - Palatal angle	computer	115.188	39.143	0.936	not significant
	manual	115.327	38.459		
Lower Incisor to Go-Me angle	computer	95.473	39.060	0.776	not significant
	manual	94.981	38.161		
Inter-incisal angle	computer	125.427	69.441	0.962	not significant
	manual	125.538	70.398		

Table 6 compares between both manual and computerised (digital) linear measurements, also no significant differences have been found between both methods for all the variables.

Table 6 Comparison between manual and digital linear measurements. ($p<0.05$)

Linear measurements	Method	Mean	Variance	P-value	Significance
Anterior cranial base (S-N) (mm)	computer	80.158	14.874	0.746	not significant
	manual	79.808	15.042		
Maxillary length anterior (mm)	computer	55.062	12.547	0.693	not significant
	manual	54.673	12.379		
Mandibular body (Go-Me) (mm)	computer	80.738	37.072	0.889	not significant
	manual	80.500	37.560		
Posterior cranial base (S-Ar) (mm)	computer	41.231	12.317	0.846	not significant
	manual	41.038	12.818		
Ramus height (Ar-Go) (mm)	computer	58.138	27.556	0.895	not significant
	manual	57.942	29.147		
Posterior face height (S-Go) (mm)	computer	93.404	44.457	0.967	not significant
	manual	93.481	45.350		
Upper Anterior Facial Height (mm)	computer	62.650	9.899	0.950	not significant
	manual	62.596	9.460		
Lower Anterior Facial Height (mm)	computer	78.362	35.186	0.971	not significant
	manual	78.423	36.494		
Anterior face height (Na-Me) (mm)	computer	139.819	46.895	0.892	not significant
	manual	140.077	45.934		

Discussion:

There are a variety of error sources in cephalometric analysis starting from radiograph taking and magnification, through landmark identification, tracing and recording the data. Because standardisation is essential in comparative studies, procedure was performed by one operator. Tracing of all radiographs was carried out randomly taking into consideration that not more than 5 radiographs were traced per day for both manual tracing and computer digitisation to minimise operator stress.In manual tracing the ruler used was millimetric and the protractor had a one degree scale, during measurement, fractions of a millimetre or degrees were rounded to the nearest half of a millimetre or half of a degree, while the computer calculated the measurements with an accuracy of 0.1mm. Some variation in the readings may be attributed to this rounding. This comes in agreement with Baumrind and Frantz [13] who suggested that measurement error could certainly be reduced considerably when instrument by which measurements could be performed to 0.1mm or 0.1 degree were used.

In this study errors due to reading of the landmarks were to be minimised, the aim was to evaluate the procedure of scanning and digitising on-screen the lateral cephalograms and of course the ability of the program to correct and produce accurate results that are comparable to the manually measured

The quality of the radiographs and magnification inherent due to the machine were not to be a factor affecting this study. Although the program provided the tools for correcting the magnification of the machine, in this study we relied on direct measurement on the radiograph itself, and the ruler used in manual measurements was used to correct the magnification due to scanning (if present).

The result shows that no significant differences were observed between the measurements of the two methods of analysis for both angular and linear variables. This suggests that computerised cephalometric analysis can produce results comparable to those produced manually. This agrees wih the result of Baskin and Cisneros. (12). Several authors concluded that computer analysis is less likely to introduce more measurement errors than hand tracing as long as landmarks are identified manually (12-15), also on-screen digitisation has been shown to be very reliable and reproducible (16) with several advantages over manual procedure like :

1.Angles and distances can be traced, calculated or listed together with the mean value for the comparison.

2.One can produce any number of copies of a computerised tracing.

3.A series of superimposition of computerised tracing can be obtained before and after therapy registered on different structures.

4.The population norms template tracing can be superimposed on a patient tracing.

5.A prognosis tracing can be generated to demonstrate the effects of possible procedures.

6.Retrieving the sorted data for clinical or research purposes.

7.Multiple analyses can be performed at the same time and different linear and angular measurements obtained separately or collectively. [17]

The software also provides lots of other capability and features that simplify and facilitate tracing procedure and comparing up to 10 radiographs in addition to treatment prediction and visual treatment objectives (VTO) and morphing of patient's photograph for photorealistic prediction of treatment outcome.

Although not included as a variable in this study, it is noteworthy to mention that time factor is of great importance nowadays, no matter how experienced or fast the operator is, measuring procedure by itself takes up more time than the identification of the landmarks and tracing the radiograph, and for a research with a greater number of radiographs to trace and measure, the effort and the time taken is increased, while with today's fast computers the time taken to identify the landmarks is the time needed to have the results ready.

In conclusion, computerised cephalometric softwares can be simple efficient and can produce results that are comparable to manually traced and analysed cephalograms. It reduces the time needed for cephalometric analysis and can help reduce the human errors introduced during the manual-measuring procedure in the conventional cephalometric analysis.

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