Innovative Journal of Medical and Health Science 3 : 5 September – October (2013) 230 - 234.

Contents lists available at www.innovativejournal.in

INNOVATIVE JOURNAL OF MEDICAL AND HEALTH SCIENCE

Journal homepage: http://www.innovativejournal.in/index.php/ijmhs

ISSN No. 2277-4939

COMPARATIVE STUDY BETWEEN MANUAL AND DIGITAL TRACINGS USING DIGITAL LATERAL RADIOGRAPHS WITH NEW CEPHALOMETRIC SOFTWARE´S VERSION

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ARTICLE INFO

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Keywords: Cephalometric measurements, Computer Software, Digital Radiography

ABSTRACT

Objectives. To assess the variability and reproducibility of a series of pre-selected cephalometric angular measurements using manual tracing (MT) and digitized tracing with the Nemoceph 8.5.2 (DT) software on digital lateral cephalometric radiographs for first time.
Material and Methods. 30 digital teleradiographs featuring 12 angular were traced cephalometrically by the same user on two occasions, once MT and once DT, one month apart.
Results. The intraclass correlation in different methods found that the observer is concordant in the two tracings where the only values below excellent were the measurements SNA, SNB and ANB in DT, which were above acceptable. The intermethod correlation for the different parameters showed that, compared to the DT, the MT were very concurrent, with all of the measurements displaying values above excellent. The points A and B affect the measurements in which they are involved, and were more notable in the digital method.
Conclusion. The validity and reproducibility of the angular measures with the Nemoceph software version 8.5.2 and the traditional method on digital lateral cephalometric radiographs show excellent concordance, however, the manual method was excellent in a greater proportion of cases than the digital method.

INTRODUCTION

Orthodontics is a speciality whose results only become visible with time. That is why in order to obtain a predictable result we must study the proportions and development of the structures involved in orthodontic treatment, as this allows us to achieve a global view of the patient and his needs. Radiographic cephalometry is a fundamental tool in orthodontic diagnosis, with significant treatment and prognosis repercussions [1]. It makes it possible to discover and analyse dental and bone discrepancies, and the progress of the treatment's visual objectives[2]. Traditionally, cephalometric tracings have been performed manually on radiographs printed on radiographic film. This technique went unchanged over the years as most progress was made in developing different studies and analysis of cranial points and measurements[3,4]. However, with the dawn of the IT age, not only could the first databases be set up featuring the values drawn from tracings [5], but also, from the mid-1990s, the use of computer programs has become the norm to perform the tracing itself.

The current proliferation of cephalometric analysis programs must not be allowed to suffocate their continued scientific study in order to provide clinical orthodontists with the opportunity to decide if the inclusion of this tool would entail a loss of quality in their diagnoses. As regards reliability, with the exception of Dolphin 8.0, whose measurements presented differences with clinical consequences [6], all of the studies unanimously agree that the computer programs' results are clinically valid. However, statistically, the differences between the studies were notable, not just in the points, angles and measurements that displayed significant inter-operator differences (which is logical and inherent to a system that studies the accuracy of measurements taken by human beings), rather also different results in intermethod significance. Some revealed the DT to be more precise [7,8] whereas others favoured MT as a reference [9].

The use of Nemoceph software in many orthodontists' work and diagnoses is a fact, and although its backing by Dr. Roth confirmed it as a quality program [10], a comparative study of the new version against the traditional method is required. The objective of this study is to assess the variability and reproducibility of a series of pre-selected angular cephalometric measurements, developing them, on the one hand, with MT, and on the other with DT using the Nemoceph 8.5.2 (DT) software.

MATERIAL AND METHODS:

30 teleradiographs from the University of Salamanca Orthodontics Clinic patients database, all in digital format, were selected using the following criteria [6,11-16]:

1-All of the radiographs were taken with the same X-Ray machine [11,13].
2-All of the cephalometric points to be registered and the soft tissue are visible [13,16].
3-Patients in occlusion [12].
4-Full dentition; without erupted or missing parts causing errors identifying the occlusal plane and tooth apex [6,16].
5-Superimposition of earposts [14,15].
6-Sample of mid-aged men and women: 25 years of age with a standard deviation of 8.7 years [13].

The radiographs were numbered 1 to 30 and no information was recorded that could have allowed the patient to be identified.

All of the radiographs were stored in an image archive in jpeg format, resolution 1360x 1840, and were taken between August 2007 and May 2009. All of the images were printed using a colour laser printer, OK1 C3300 (Oki Electric Industry Co., Ltd., Japan, Tokyo, Minato-ku) at maximum possible quality on white pages with a print area of 195x255mm. Each radiograph was placed on a flat X-ray film viewer DILOS 100 (Jejoong medical co., Ltd., Wonju City, Gangwon-do) for manual tracing.

Each radiograph was traced four times, producing a sample of 120 digital tracing, subdivided from 1 to 4 in groups, where:

1-Subgroup A: DT using the Nemoceph program.
2-Subgroup B: DT 30 days later.
3-Subgroup C: MT on printed copy.
4-Subgroup D: MT on printed copy 30 days later.

12 cephalometric points were used for the tracing, combined into 11 angular measurements:

- Saddle angle: Angle determined by points N, S, and Ar.
- Articular angle: Angle determined by points S, Ar, and Go.
- Go angle: Angle determined by points Ar, Go, and Me.
- Upper go angle: Angle determined by points Ar, Go, and Na.
- Lower go angle: Angle determined by points Na, Go, and Me.
- SNA: Angle determined by points S, N, and A.
- SNB: Angle determined by points S, N, and B.
- ANB: Angle determined by points A, N, and B.
- U1/ S-N: Angle formed between the axis of the maxillary incisor to SN plane.
- L1/Go-Me: Angle formed by the intersection of the mandibular incisor axis to the plane between points Go and Me.
- U1/L1: Angle formed by the intersection of the mandibular incisor axis to the maxillary incisor axis.

The program used for DT was Nemoceph Dental Studio NX (Software Nemotec SL, Spain, Madrid), version 8.5.2. It was acquired by the operator in October 2009.

The following were used for statistical analysis:

- Student T tests to compare concordance between subgroup A (DT) and B (DT conducted 30 days later), and between subgroup C (MT) and D (MT conducted 30 days later).
- Multiple comparison with (*analysis of variance*) of the 4 cephalometric tracing groups.
- Intraclass correlation coefficients to assess intra-observer concordance at different times for both analogue and digital among different parameters.
- Intermethod correlation, using the Pearson correlation coefficient to assess the correlation between the parameters obtained with DT and MT.
- The statistical analysis computer program used was SPSS v.17 (IBM, USA, Chicago). A $p<0.05$ was considered statistically significant for ANOVA and the Student T tests.

RESULTS

The Student T tests to contrast concordance of the DT performed at baseline on 30 days later, did not show statistical difference. The same way shown for the concordance of the MT (Results not shown). The multiple comparison using ANOVA (analysis of variance) of the cephalometric data based on the type of tracing, did not find significant differences in either the DT nor the MT separately, nor within each method or between the methods (Table I).

Table I: One-way ANOVA Tests for comparison of the cephalometric parameters for the digital and analogue tracing between the subgroups A and B (DT using the Nemoceph program and DT 30 days later), C and D (MT on printed copy and MT 30 days later).

cephalometric variables	*Subgroup*	*N*	*Mean*	*Standard deviation.*	*Standard deviation*	*p-value of the ANOVA test*
Saddle angle	Subgroup A	30	126.04	4.61	0.84	0.58
	Subgroup B	30	125.33	4.46	0.81	
	Subgroup C	30	126.67	4.78	0.87	
	Subgroup D	30	126.83	4.64	0.85	
Articular angle	Subgroup A	30	146.78	7.78	1.42	0.18
	Subgroup B	30	148.40	7.24	1.32	
	Subgroup C	30	144.10	8.43	1.54	
	Subgroup D	30	145.77	6.96	1.27	
Go angle	Subgroup A	30	120.83	6.79	1.24	0.87
	Subgroup B	30	119.92	6.50	1.19	
	Subgroup C	30	121.07	5.85	1.07	
	Subgroup D	30	121.07	5.49	1.00	
Upper Go angle	Subgroup A	30	47.74	4.53	0.83	0.72
	Subgroup B	30	47.08	4.30	0.79	
	Subgroup C	30	47.97	4.08	0.75	
	Subgroup D	30	48.25	3.42	0.62	
Lower Go angle	Subgroup A	30	73.10	4.54	0.83	0.99
	Subgroup B	30	72.84	4.52	0.83	
	Subgroup C	30	73.10	4.37	0.80	
	Subgroup D	30	72.85	4.37	0.80	
SNA	Subgroup A	30	79.59	4.18	0.76	0.57
	Subgroup B	30	79.73	3.70	0.67	

	Subgroup C	30	78.47	5.57	1.02	
	Subgroup D	30	78.60	3.69	0.67	
SNB	Subgroup A	30	77.50	4.10	0.75	0.80
	Subgroup B	30	77.22	3.87	0.71	
	Subgroup C	30	77.13	5.79	1.06	
	Subgroup D	30	76.40	3.45	0.63	
ANB	Subgroup A	30	2.09	1.90	0.35	0.15
	Subgroup B	30	2.50	1.87	0.34	
	Subgroup C	30	1.33	2.50	0.46	
	Subgroup D	30	2.20	1.77	0.32	
U1/ S-N	Subgroup A	30	102.47	6.83	1.25	0.10
	Subgroup B	30	100.58	6.02	1.10	
	Subgroup C	30	104.53	5.86	1.07	
	Subgroup D	30	103.33	6.36	1.16	
L1/Go-Me	Subgroup A	30	95.44	7.47	1.36	0.70
	Subgroup B	30	95.53	8.17	1.49	
	Subgroup C	30	93.63	8.26	1.50	
	Subgroup D	30	93.90	7.66	1.40	
U1/L1	Subgroup A	30	128.42	8.13	1.48	0.52
	Subgroup B	30	130.27	9.85	1.80	
	Subgroup C	30	126.73	8.58	1.57	
	Subgroup D	30	128.37	9.58	1.75	

The intraclass correlation to value intra-observer concordance in the different methods (analogue and digital) for the different parameters used as the interpretation scale for value kappa proposed by Landis and Koch [17], which considers a value greater than or equal to 0.40 as acceptable and values in excess of 0.75 as excellent, found that the observer is concordant in the two tracings, where the average for all angular MT measurements (average:0.91) was above the DT average (average:0.80). The intraclass correlation coefficient for each angular measurement attained a greater or equal value in MT than in DT except in two angles (saddle and interincisal), which were slightly lower (Table II). The only values below excellent, but above acceptable, were the measures SNA; SNB; ANB in DT (Table II).

Table II: Intraclass correlation coefficient to assess intra-observer concordance in different methods (analogue and digital) for different parameters.

Cephalometric variables	*Manual Tracing*	*Digitized Tracing*
Saddle angle	0.92	0.95
Articular angle	0.89	0.83
Go angle	0.94	0.94
Upper Go angle	0.92	0.88
Lower Go angle	0.98	0.94
SNA	0.94	0.55
SNB	0.98	0.59
ANB	0.79	0.64
U1/ S-N	0.86	0.81
L1/Go-Me	0.91	0.91
U1/L1	0.82	0.83
Average	**0.90**	**0.81**

Interpretation scale for value of kappa considering a value greater than or equal to 0.40 as acceptable and values above 0.75 as excellent (19).

DISCUSSION:

MT has been the method of choices for years, but its computer application has allowed larger studies to be conducted by working with greater amounts of data [5]. Hence, the trend has been to replace the analogue or traditional method with its computerised counterpart, both to save space (due to medical history filing) and time[7]. Although it is true that a "gold standard" computer program is yet to be found for this type of study, MT (always under the observer's watchful control) serves to determine measurements' consistency and repeatability given that it is the method which has been used for longest and for which most validity studies have been conducted [18]. Equally, any investigation aiming to demonstrate the precision of digital cephalometry must choose between the use of cephalometric measurements or cephalometric points [15]. This study used measurements because they are the ultimate goal of cephalometry (providing the data to determine treatment) and recent works [10,13] use them because they are the element for which we must ascertain whether modification would be worthwhile.

The intermethod correlation (Table III) to assess concordance between the two methods (average between the two temporal assessments) for the different parameters showed that, compared with DT, MT was very concordant (r=0.87), especially for the go, the interincisal and the saddle angles. The least consistent parameter between the two methods was the ANB.

Table III intermethod correlation to assess inter-method concordance (average between temporal assessments) for different parameters.

Cephalometric variables	**(Correlation Coefficient)**
Saddle angle	0.91
Articular angle	0.85
Go angle	0.94
Upper Go angle	0.92
Lower Go angle	0.96
SNA	0.79
SNB	0.86
ANB	0.76
U1/ S-N	0.84
L1/Go-Me	0.83
U1/L1	0.91
Average	**0.87**

Interpretation scale for value of kappa considering a value greater than or equal to 0.40 as acceptable and values above 0.75 as excellent (19).

In our study we used MT as a comparative method and it proved more reliable (an average of 0.90 in intramethod correlation) than DT (with an average intramethod correlation of 0.81) by showing a higher value. However, it should be taken into account that both methods obtained correlation values classified as excellent as per the interpretation scale for value kapa proposed by Landis and Koch [17]. Consequently, the digital tool used is a reliable clinical tool. The superior results achieved using MT compared to DT can be explained by the fact it is the method taught to young orthodontists at university. At the same time, it is the most natural method for them given that drawing is a skill learned from infancy and is conducted on paper with direct visualisation using pencil, just like MT. It is therefore not surprising that MT provides superior values when studied in individuals who were raised developing these skills [19-20].

The results of this study, starting with intraclass MT correlation (Table II), and taking correlations above 0.75 as excellent, according to Landis and Koch [17], shows that the observer is consistent in tracing most of his measurements (which exceed that value reaching 0.98 in some cases), validating it as apt for the study. ANB, which is the difficult, low reproducibility value [21], displays the lowest value with a correlation of 0.79. However, this remains classified as excellent.

In intraclass digital method correlation (Table II), its validity compared to the manual method obtained a slightly higher value for the saddle (0.95 compared to 0.92) and interincisal angles (0.83 compared to 0.82), but was lower in the ANB (0.79 compared to 0.64), SNA (0.94 compared to 0.55) and SNB (0.98 compared to 0.59) measurements. According to Landis and Koch [17], these values are acceptable. However, they indicate that the reliability of these values is lower and MT is more reliable. In previous studies these measurements showed that: a) SNB is a measurement in which significant but clinically acceptable differences had already been found [22]; b) SNA in another difficult measurements [23,24] which shows that the cephalometric points located on poorly defined edges, such as nasion and point A, seem to show higher error rates. It is therefore logical that ANB measurement be affected as it features three difficult points.

As regards intermethod correlation, the reproducibility or repetition precision of the tracings using different methods, set out in Table III, showed the lowest values in SNA (0.79) and ANB (0.76), which remain excellent under the aforementioned Landis and Koch [17] criteria.

The cephalometric points chosen were studied in angular measurements not affected by the discrepancies between the different study formats (printed and digital) that could alter the results [25], and, in turn, in measurements using said points on different occasions, without dependence, meaning that their reliability can be assessed by comparing the results.

When designing this work, we opted for the analysis of preselected cephalometric measurements rather than the location and study of points using Cartesian axes. However, these tools can be used to analyse the most difficult cephalometric points. The statistical results showed their lowest values (which were nevertheless clinically acceptable) in the SNA, SNB and ANB angles of the digital tracing (Table II), which mirrored previous studies [6], and was coherent with the doubts that arose in the 1990s with DT [23,24] and in line with the problems put forward in recently conducted studies [26]. By analysing in depth the component cephalometric points (S, N, A and B), we can assert that:

1. Point S is involved in the lower accuracy measurements. Taking into account that S is involved in two other measurements (saddle and articular angles) which have attained high correlation values, it can be highlighted as the cause.
2. N can be a difficult point when the naso-frontal suture is not viewed accurately, showing the angles or measurements involving lower correlation [13] and more affected than other cephalometric measurements by image compression [27]. However, it is present in two other measurements: lower go angle and saddle angle. The lower go angle is the measurement with the highest intermethod correlation in the study. As regards the saddle angle, not only does it display high correlation but it is also the only measurement with a greater intraclass correlation in DT. We can therefore assert that N does not affect measurements with lower correlations.
3. Point A is usually difficult because of its low reproducibility [15] because it is on a poorly defined edge[23,24]. In this study, all of the measurements in which it is involved display low correlation values, allowing us to assert that it is a difficult cephalometric point.
4. Point B, studied in measurement SNB, was the subject of other, larger studies that found a significant difference between DT and MT [22]. In this study, in light of the results of the measurements in which it is involved, we can conclude that it is a difficult point.

The use of 30 digital format teleradiographs endows the study with sufficient breadth to validate its results. The uniformity criteria followed: same X-ray machine, identification of all structures involved, superimposed earposts and age, followed the guidelines of the reference articles [6,11-16]. The same radiographs were used in digital and printed format as it would not have been ethical (given the heightened radiation exposure for the patient) to take two radiographs (one digital and one analogical) to obtain both system, nor viable (due to the added cost of a system to take both images simultaneously) [15]. Furthermore, to determine the operator's reliability and reproducibility, the 30 radiographs were traced again by the same operator using both methods one month after the original tracing.

For MT, each image was printed to scale using the highest quality (photographic) laser printer, the method used in previous studies, the validity of which has been demonstrated both clinically [14,28] and for use in studies [16]. No distortion was found in this study, the results of which have proven to be more reliable. Moreover, the DT method used, displayed on a computer screen and traced directly, has also been validated by other authors [28]. In this tracing, all of the radiographs were originally stored in an image archive in jpeg format, which the program supports, and which has proven valid [29], resolution 1360x1840, taken between August 2007 and May 2009. The image files had a resolution of 300dpi and 8 bits of depth, as recommended by the software's manufacturer, in order to achieve image clarity and facilitate enlargement. Higher resolutions have disadvantages in terms of file size and have not proven to produce better results [27,29]. Furthermore, the points selection criteria used was based on bibliographic review of the articles published over the last decade, controversial the most conflictive of them.

The results and reliability displayed by the angular measurements are considered acceptable, however, it would be worth expanding this study to include different observers, assessing younger observers with better IT skills and their more developed means, using linear measurements and other difficult points.

CONCLUSIONS

1. The validity and reproducibility of angular measures on digital lateral cephalometric radiographs using the Nemoceph software version 8.5.2 and the MT of digital lateral radiographs on printed paper show excellent

correlation, however, the MT was excellent in a greater proportion of cases than the DT.

2. The measurements ANB, SNA and SNB achieved greater correlation in MT than in DT. In said measurements, DT is valid but the difference over MT does not make it the method of choice. The saddle and interincisal measurements achieved greater correlation in DT.
3. The points A and B affect the measurements in which they are involved, and were more notable in the DT.

COI STATEMENT:

The authors declare no conflict of interest.

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