A comparative study of manual vs. computerized cephalometric analysis

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Abstract

Objective: To conduct a comparative analysis between manual and computerized tracings using specific software, in order to define inter- and intraobserver results. **Methods:** A sample was used consisting of 50 standardized lateral cephalometric radiographs, of male and female patients of various age groups. The radiographs were analyzed by two observers, who each performed the manual and computerized tracings of all 50 radiographs. Angular and linear measurements were obtained, which were later submitted to the Mann-Whitney test in order to compare the inter- and intraobserver results between the two types of tracings. **Results and Conclusions:** the study concluded that confidence can be increased in tracings obtained from computer-assisted cephalometric analysis, as the discrepancies found between inter- and intraobserver tracings, both manual and computerized, were mostly not statistically significant.

Keywords: Radiography. Cephalometrics. Craniometry.

INTRODUCTION AND LITERATURE REVIEW

The works of Broadbent and Hoffrat in 1931 pioneered the development of cephalometrics[2] and its application in dentistry, especially orthodontics. It has since become essential in the diagnosis, planning[10] and result evaluation of cases treated with orthodontics.

When performing a cephalometric analysis, it is necessary to define precisely the manner in which the many different cephalometric landmarks will be determined, so that the exams have universal application—which is, in fact, one of its main qualities. Indeed, it was the wide standardization of analysis methods that made possible the development of cephalometric radiography as a diagnostic tool.[19]

Cephalometric analysis has been used as a tool for the evaluation of anthropometric data since the 1930s. It was introduced in the field of orthodontics for the study of human facial growth patterns, to aid in the diagnosis and planning of treatments for dentofacial deformities,

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and in the study of immediate and long-term defects of these treatments. More recently, it has gained increased relevance in the evolution of orthognathic surgery.

Currently, cephalometric radiography can be regarded as a product of the evolution in anthropometric and archeological studies. With regard to the study of bones, the need emerged to standardize the communication between the fields of archeology and anthropometrics, so that descriptions became more precise and made possible objective comparisons of bone morphology. This led to the creation of bone measurement procedures, which became known as osteometry, while the specific measurement of cranial bones was named craniometry. Cephalometrics, meanwhile, consists of measuring the entire head, including the surrounding soft tissue.

Image thickness and resolution, anatomical complexity and superimposition of hard and soft tissue, and the experience of the observers when looking for a particular landmark are important factors that can influence the identification of the landmark.[17]

Traditional cephalometric analysis is preformed by tracing radiographic landmarks on an acetate sheet and using the landmarks to measure the desired linear and angular values. This traditional method using manual tracing can take time and the linear and angular cephalometric measurements obtained manually using a ruler and protractor can lead to errors.[5]

The objective of using computers was to verify whether there would be a reduction in reproducibility errors of measurements in cephalometric analyses and whether the tracer's experience had a significant influence. It was observed that there was not a satisfactory reproduction of the measurements involving incisors, thus demonstrating that experience is not a factor that can in itself significantly reduce the margin of systematic error in computer-assisted Steiner analysis.[16]

A comparative study between the manual and computerized cephalometric measurement methods was performed by Richardson[14] in 1981. He compared 50 lateral cranial radiographs of 12-year-old children, half male and half female. Fourteen landmarks were defined in that study: S, N, anterior nasal spine, subspinal, incisal and zenith of the maxillary incisor, incisal and zenith of the maxillary incisor, supramenton, pogonion, gnathion, molar, pterygomaxillary and articulare. The conclusion was that traditional methods were inferior in comparison to digital procedures, but not alarmingly so, and in some cases traditional methods produced more precise results.

As the use of computers in assisting cephalometric analysis gained popularity, both in research and in clinical applications, Nimkarn and Miles[12] studied the reliability of computer-assisted cephalometrics in 1995. Forty radiographs from the same x-ray machine were used and chosen at random. Each radiograph was traced in acetate paper, and the images of the radiographs and tracings were captured in a video camera, projected onto a monitor, where the landmarks were digitized. The cephalometric measurements were obtained using Quick Ceph 5.1 software (Quick Ceph Systems, USA). The program performed the calculations for all 40 measurements, from 22 marked landmarks. In order to assess methodology errors and identify the source of errors, the study consisted of five parts: 1) Reproducibility of computerized measurement technique; 2) Video imaging, digitalization and software; 3) Digitalization and software; 4) Computer vs. manual measurement; 5) Software calibration and operator digitalization errors. The results showed that the measurements performed in the computer were comparable to manual measurements, with no statistically significant differences.

One study involving two orthodontists, who each twice traced 21 cephalometric landmarks in 100 radiographs obtained through the traditional method and 100 radiographs obtained from digital imaging, demonstrated a coincidence in intraobserver cephalometric landmarks and little interobserver difference.[9] The authors also highlighted that the linear and angular measurements were more precise in the digitally obtained radiographs, emphasizing that the quality of digital radiographs facilitates cephalometric measurements.[9]

The objective of the present work was to compare the measurements made using computerized cephalometric tracing software to manual measurements, with the purpose of establishing the level of agreement between them, as well as evaluating intra- and interobserver results.

METHODOLOGY

In order to perform the current study, a sample was used consisting of 50 lateral cephalometric radiographs belonging to patients from the same dental radiology center, selected according to the following criteria: Random selection, patients from both genders, patients from several age groups.

The radiographs were measured with two different methods, by two observers, named: Observer 1—consisting of 25 lateral cephalometric radiographs, in which linear and angular measurements were made using both the manual method (Fig 1) and computer-assisted method (Fig 2) with Cef-X 2001 software (CDT, Cuiabá, Brazil) under USP analysis; and Observer 2—consisting of 25 lateral cephalometric radiographs, in which linear and angular measurements were made using both the manual method and computer-assisted method with Cef-X 2001 software under USP analysis.

After each observer had measured their 25 radiographs, the x-rays were exchanged between the two observers, so that both inter- and intraobserver results could be obtained, totaling an evaluation of 50 radiographs per observer.

After calibration of observers 1 and 2, in order to reduce errors during the study and standardize the procedures, the tracing and

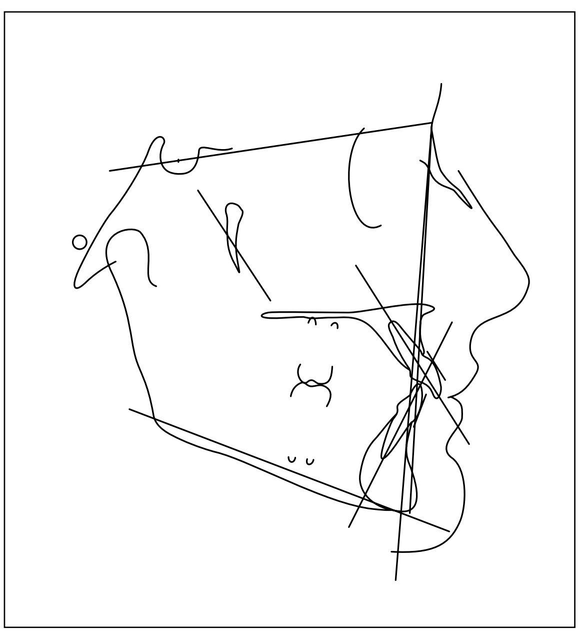

FIGURE 1 - Manual cephalometric tracing.

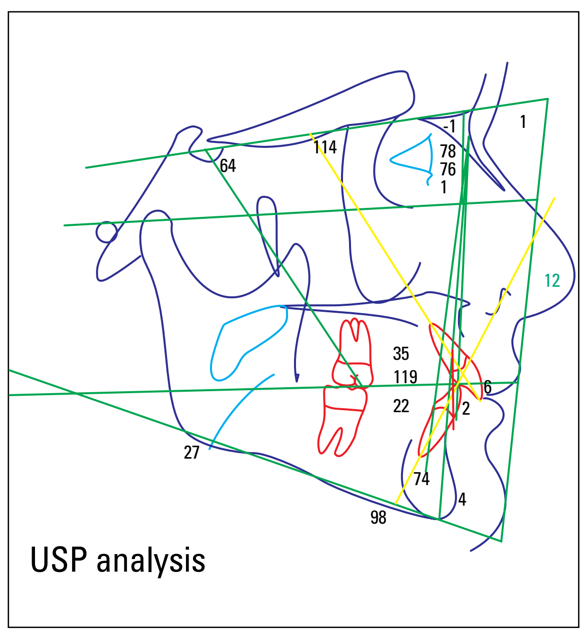

FIGURE 2 - Computerized cephalometric tracing.

cephalometric measurements were obtained in ultraphan paper. The drawings of anatomical structures and cephalometric landmarks, and the USP analysis were made using a light box in a dark room. A maximum of 10 radiographs were evaluated per day by each observer, in order to avoid fatigue leading to casual errors.

Cephalometric measurements were established as follows: angular and linear measurements. In both methods of cephalometric tracing evaluated in this work, the linear measurements defined were 1-NA and 1-NB, and the angular measurements were SNA, SNB, ANB, SNGn and IMPA.

The data were noted on a record sheet and tabulated on a computer for later tests.

The radiographs were later digitized and stored in a computer for computerized cephalometric analysis. After that stage, the radiographs were imported into the Cef-X program, where they were calibrated in order to avoid any distortion of the program with the original radiograph. Next, computer measurements were made using the Cef-X computer program, by marking the landmarks directly on the screen using the mouse cursor. Next, the data provided by the program were calculated and a report sheet model was issued for each radiograph.

STATISTICAL ANALYSIS

The measurements obtained from the manual and computerized cephalometric tracings were organized in tables and later subjected to statistical analysis through the Mann-Whitney test, which is a non-parametric test performed to compare two independent and same-size samples, whose scores have been measured ordinally.[1]

RESULTS

For each factor of the USP-standard cephalometric analysis, the arithmetic mean was obtained for the manual and computerized measurements of all tables.

The comparison of measurements between the manual and computerized tracings of Observer 1, after the test was applied, did not show significant differences (Table 1).

The comparison of measurements between the manual and computerized tracings of Observer 2, after the test was applied, showed that the angular measurements did not show significant differences, whereas linear measurements (1-NA and 1-NB) showed statistically significant differences (Table 2).

The comparison of the measurements between the manual tracings of observers 1 and 2, after the

TABLE 1 - Mean of the measurements obtained using the different methods, according to the process of Observer 1, and the result of the Mann-Whitney test.

MEAN (μ) ± STANDARD DEVIATION (SD)			
Measurements	Manual μ1 ± SD	Computerized μ1 ± SD	P-value
SNA (degrees)	83.53 ± 4.46	83.74 ± 4.45	0.73 n.s.
SNB (degrees)	79.54 ± 4.48	80.00 ± 4.45	0.64 n.s.
ANB (degrees)	3.99 ± 3.01	4.45 ± 2.61	0.85 n.s.
SNGn (degrees)	67.71 ± 4.30	67.25 ± 4.18	0.63 n.s.
IMPA (degrees)	95.79 ± 7.99	95.38 ± 8.41	0.90 n.s.
1-NA (mm)	7.20 ± 2.93	6.60 ± 3.65	0.21 n.s.
1-NB (mm)	6.80 ± 2.74	7.10 ± 3.60	0.77 n.s.

n.s. = non-significant ($p > 0.05$); * = significant ($p < 0.05$).

TABLE 2 - Mean of the measurements obtained using the different methods, according to the process of Observer 2, and the result of the Mann-Whitney test.

MEAN (μ) ± STANDARD DEVIATION (SD)			
Measurements	Manual μ2 ± SD	Computerized μ2 ± SD	P-value
SNA (degrees)	83.44 ± 3.85	84.13 ± 4.77	0.57 n.s.
SNB (degrees)	79.18 ± 4.65	79.97 ± 4.80	0.54 n.s.
ANB (degrees)	4.38 ± 2.47	5.53 ± 3.00	0.83 n.s.
SNGn (degrees)	68.70 ± 4.42	67.30 ± 4.56	0.33 n.s.
IMPA (degrees)	94.82 ± 12.06	95.74 ± 6.49	0.67 n.s.
1-NA (mm)	3.80 ± 0.53	6.71 ± 4.12	0.00001 *
1-NB (mm)	2.86 ± 0.61	7.28 ± 3.39	0.00001 *

n.s. = non-significant ($p > 0.05$); * = significant ($p < 0.05$).

TABLE 3 - Mean of the measurements obtained using the Manual method, according to the processes of Observers 1 and 2, and the result of the Mann-Whitney test.

MEAN (μ) ± STANDARD DEVIATION (SD)			
Measurements	Manual μ1 ± SD	Manual μ2 ± SD	P-value
SNA (degrees)	83.53 ± 4.46	83.44 ± 3.85	0.94 n.s.
SNB (degrees)	79.54 ± 4.48	79.18 ± 4.65	0.99 n.s.
ANB (degrees)	3.99 ± 3.01	4.38 ± 2.47	0.85 n.s.
SNGn (degrees)	67.71 ± 4.30	68.70 ± 4.42	0.65 n.s.
IMPA (degrees)	95.79 ± 7.99	94.82 ± 12.06	0.46 n.s.
1-NA (mm)	7.20 ± 2.93	3.80 ± 0.53	0.00001 *
1-NB (mm)	6.80 ± 2.74	2.86 ± 0.61	0.00001 *

n.s. = non-significant ($p > 0.05$); * = significant ($p < 0.05$).

TABLE 4 - Mean of the measurements obtained using the Computerized method, according to the processes of Observers 1 e 2, and the result of the Mann-Whitney test.

MEAN (μ) ± STANDARD DEVIATION (SD)			
Measurements	Computerized μ1 ± SD	Computerized μ2 ± SD	P-value
SNA (degrees)	83.74 ± 4.45	84.13 ± 4.77	0.53 n.s.
SNB (degrees)	80.00 ± 4.45	79.97 ± 4.80	0.91 n.s.
ANB (degrees)	4.45 ± 2.61	5.53 ± 3.00	0.83 n.s.
SNGn (degrees)	67.25 ± 4.18	67.30 ± 4.56	0.85 n.s.
IMPA (degrees)	95.38 ± 8.41	95.74 ± 6.49	0.62 n.s.
1-NA (mm)	6.60 ± 3.65	6.71 ± 4.12	0.21 n.s.
1-NB (mm)	7.10 ± 3.60	7.28 ± 3.39	0.76 n.s.

n.s. = non-significant ($p > 0.05$); * = significant ($p < 0.05$).

TABLE 5 - Mean of the measurements taken using the different methods, according to the processes of Observers 2 and 1, and the result of the Mann-Whitney test.

MEAN (μ) ± STANDARD DEVIATION (SD)			
Measurements	Manual μ2 ± SD	Computerized μ1 ± SD	P-value
SNA (degrees)	83.44 ± 3.85	83.74 ± 4.45	0.45 n.s.
SNB (degrees)	79.18 ± 4.65	80.00 ± 4.45	0.49 n.s.
ANB (degrees)	4.38 ± 2.47	4.45 ± 2.61	0.65 n.s.
SNGn (degrees)	68.70 ± 4.42	67.25 ± 4.18	0.23 n.s.
IMPA (degrees)	94.82 ± 12.06	95.38 ± 8.41	0.44 n.s.
1-NA (mm)	3.80 ± 0.53	6.60 ± 3.65	0.00001 *
1-NB (mm)	2.86 ± 0.61	7.10 ± 3.60	0.00001 *

n.s. = non-significant ($p > 0.05$); * = significant ($p < 0.05$).

TABLE 6 - Mean of the measurements taken using the different methods, according to the process of Observers 2 and 1, and the result of the Mann-Whitney test.

MEAN (μ) ± STANDARD DEVIATION (SD)			
Measurements	Computerized μ2 ± SD	Manual μ1± SD	P-value
SNA (degrees)	84.13 ± 4.77	83.53 ± 4.46	0.97 n.s.
SNB (degrees)	79.97 ± 4.80	79.54 ± 4.48	0.96 n.s.
ANB (degrees)	5.53 ± 3.00	3.99 ± 3.01	0.86 n.s.
SNGn (degrees)	67.30 ± 4.56	67.71 ± 4.30	0.95 n.s.
IMPA (degrees)	95.74 ± 6.49	95.79 ± 7.99	0.94 n.s.
1-NA (mm)	6.71 ± 4.12	7.20 ± 2.93	0.89 n.s.
1-NB (mm)	7.28 ± 3.39	6.80 ± 2.74	0.88 n.s.

n.s. = non-significant ($p > 0.05$); * = significant ($p < 0.05$).

test was applied, showed that the angular measurements did not show statistically significant differences, whereas linear measurements (1-NA and 1-NB) showed statistically significant differences (Table 3).

The comparison of measurements between the computerized tracings of observers 1 and 2, after the test was applied, showed that the differences were not significant (Table 4).

The comparison of the measurements between the manual and computerized tracings of observers 2 and 1, respectively, after the test was applied, showed that the angular measurements did not show statistically significant differences, whereas linear measurements (1-NA and 1-NB) showed statistically significant differences (Table 5).

The comparison of measurements between the computerized and manual tracings of observers 2 and 1, respectively, after the test was applied, showed that the differences were not significant (Table 6).

DISCUSSION

The studies related to the same theme and with a similar purpose as this research, reviewed in literature, show a lack of criteria with regard to the choice of cephalometric landmarks and the ideal linear/angular measurements to be used in studies of this nature.[3,4,6,7,12,16]

Justifications can be made with regard to the selection of landmarks and cephalometric measurements in this type of work, as exemplified in the ease of locating the landmarks, providing higher reliability and precision, which can directly influence the measurement,[13,17,18] as the reproducibility of the measurement is part of different types of cephalometric analysis proposed by several authors.[2,5,7,8,11,16]

The manual method required higher time expenditure, but it is the most common method for tracing, identifying landmarks, measuring distances and angles between the locations of the landmarks,[15] in addition to having a high possibility of error. The authors recommended the replication of tracings as a good measure to diminish the possibility of error with this method.[16]

With the advent of the computer-assisted method, a decrease in the differences of cephalometric measurements began to be observed, as the precision of the measurements became significantly more accurate due to the intrinsic characteristics of measuring computer pixels.[7]

The computer reduced, although discretely, the possibility of differences, as it is more secure than the manual method. When locating landmarks defined as being more inferior or deep in a given bone contour—for instance, points A, B and N—the computerized method proved to be more reliable than the manual method.[13]

However, in order to obtain a computer-assisted cephalometric tracing, it is important to have anatomical/radiographic knowledge of the cephalometric structures required for marking the landmarks, even though it becomes easier and faster to identify anatomical structures and mark the landmarks, as different features of the software can be used—such as zoom, contract and brightness.

With respect to marking the cephalometric landmarks related to the location of N, B and A vertically, we verified that the difficulty in adequately reproducing them is similar in the manual and computerized methods.[14,16]

With regard to angular measurement SNGn, although it is a measurement that involves the landmark N, which is difficult to locate in both methods, it is not statistically different in both methods of cephalometric tracing.[8,18]

The angular measurement IMPA is easily measurable, as it does not involve hard-to-find landmarks described in this study. It also did not show statistically significant changes in both methods.[8]

Linear measurements 1-NA and 1-NB, which require the location of points A and B (which in turn are equally difficult to reproduce both in the manual and computer-assisted methods), did not show statistically significant differences in this study when comparing the measurements of the manual and computerized tracings of Observer 1, when comparing interobserver computerized tracings, and when comparing the computerized tracing measurements of Observer 2 with the manual tracing measurements of Observer 1.[8]

However, for linear measurements 1-NA and 1-NB, when comparing the manual and computerized tracings of Observer 2, there were statistically significant differences in this study.[16] When comparing interobserver manual tracings and when comparing the manual tracing of Observer 2 with the computerized tracing of Observer 1, there were also statistically significant differences in this study.[4]

The interobserver variations found in some studies may be caused by variations in training and experience or by the nature of landmark identification. Moreover, intraobserver variations may be the results of lighting and image position.[15]

CONCLUSION

According to the results obtained through the methodology used in this research, it is concluded that:

1) The confidence can be increased in the results of cephalometric tracings obtained from computers, as the discrepancies found between the measurements of manual and computerized tracings were, in their majority, statistically non-significant.

2) Intraobserver linear measurements showed statistically significant differences between manual and computerized tracings for one of the observers.

3) Interobserver linear measurements showed statistically significant differences both in manual tracing and between manual and computerized tracings. However, there was no statistical difference in the results of computer-assisted tracings.

4) The time spent to perform manual tracing was greater than for computerized tracing.

5) The use of features of the computerized cephalometric tracing software, such as zoom, changes in brightness, density and contrast, were useful to determine cephalometric landmarks.

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