ORIGINAL ARTICLE

Comparative study between manual and digital cephalometric tracing using Dolphin Imaging software with lateral radiographs

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Abstract

Objective: The purpose of this study was to compare angular and linear cephalometric measurements obtained through manual and digital cephalometric tracings using Dolphin Imaging® 11.0 software with lateral cephalometric radiographs. **Methods:** The sample consisted of 50 lateral cephalometric radiographs. One properly calibrated examiner performed 50 manual and 50 digital cephalometric tracings using eight angular measurements (FMA, IMPA, SNA, SNB, ANB, 1.NA, 1.NB, Y-Axis) and six linear measurements (1-NA, 1-NB, Co-Gn, Co-A, E Line-Lower lip and LAFH). Results were assessed using Student's t-test. **Results:** The results showed no statistically significant differences in any of the assessed measurements ($p > 0.05$). **Conclusions:** Conventional and computerized methods showed consistency in all angular and linear measurements. The computer program Dolphin Imaging® 11.0 can be used reliably as an aid in diagnosing, planning, monitoring and evaluating orthodontic treatment both in clinical and research settings.

Keywords: Cephalometry. Orthodontics. Computerized diagnosis.

INTRODUCTION

In 1931, Orthodontics ushered in the age of radiographic cephalometry grounded in the historical work of Broadbent in the United States and Hofrath in Germany, who simultaneously developed techniques for obtaining standardized radiographs of the head. Cephalometric radiography is a valuable tool in diagnosis, prognosis, treatment planning and evaluation, as well as in studies on the growth and development of the dental and craniofacial complex.[1,7]

Cephalometric tracings can be performed by manual and/or computerized methods. The manual method was, for a long time, the only method used for implementing and obtaining cephalometric tracings, and angular and linear

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measurements required for their interpretation. The main disadvantage of this method lies in the fact that it is relatively time-consuming, particularly for orthodontists.[5,27]

Continuous technological advances in computing combined with scientific advances in dental radiology resulted in the development of computer programs designed to perform cephalometric tracings and measurements, and different types of analysis. Therefore, in the late '60s and early '70s cephalograms began to take center stage as computers played an increasingly key role in the search for quantitative information regarding orthodontic diagnosis and events associated with craniofacial growth and development.[27] A substantial number of programs are available in the domestic and international market offering a wide array of features and variable prices.[15] They have been widely used in orthodontics, especially for storing documentation and facilitating cephalometric tracings.[18] It is undeniable that Orthodontics has benefitted more than any other dental specialty from computerization in structuring and developing its activities while incorporating computer resources to acquire and use information quickly and efficiently.[21] But given the constant refinement of both software and hardware, it is important for professionals to update their knowledge on an ongoing basis, since computer updates and upgrades are incontestable.

In 1994, during the 2nd Symposium on Computers in Orthodontics, held during the 9th Brazilian SPO Orthodontic Conference, Dolphin Imaging software was first introduced in Brazil. This computer program features high technology and works with cutting-edge graphics software. It provided an alternative way to perform cephalometric tracings without using conventional cephalometric radiographs and therefore paved the way for the use of 3D Cephalometry.[19] It can perform more than 120 different linear and angular cephalometric analyses, all widely used in Orthodontics and Surgery. Dolphin Imaging software and the emergence of cone beam CT (CBCT) were pioneers in the processing of DICOM files (CT scans) and corresponding 3D cephalometric volumetric and cephalometric measurements in Dentistry.[14] Today, images acquired through CT scans provide 100% reliably accurate measurements. This diagnostic and planning technology is available in major centers worldwide. In the United States this program is widely used by orthodontists and surgeons, attesting to its quality and credibility. In Brazil there are approximately 129 users. This limitation is due to the high cost of the program in view of the country's current socioeconomic reality.

Computer technology has brought to dental practice easier archiving while facilitating the search of administrative and financial information. It has also strengthened the communication channels between professionals and patients by providing information, guidance, documentation images and photographs. The manipulation of these images made it possible to develop computer presentations in programs like Microsoft PowerPoint and others, broadening their use in courses and conferences.[12,19]

There is no escaping modernization and the great benefits this digital evolution has to offer. Since the cephalometric analysis method is frequently used by orthodontists and researchers and due to continuous advances in Cephalometric software, the need was felt to assess and compare the accuracy of cephalograms by manual methods and digital imaging using Dolphin® 11.0 software (Dolphin Imaging and Management Solutions, Chatsworth, Calif.).

MATERIAL AND METHODS

This cross-sectional study used a random sample of 50 cephalograms of 23 male and 27 female subjects with permanent dentition (up to second molars) with a mean age of 18 years and four months. These tests were requested prior to treatment as part of the diagnostic elements from the archives of the Professor José Édimo Soares Martins Specialization Program in Orthodontics and Dentofacial Orthopedics, School of Dentistry, Federal University of Bahia (FOUFBA).

These lateral radiographs were obtained in the same radiological clinic and were performed with the patient's head immobilized by a cephalostat guided by the Frankfort Horizontal plane, parallel to the ground and perpendicular to the mid-sagittal plane.

Manual method

After sample selection, a single examiner performed the cephalometric tracings manually. The radiographs were divided into five groups of ten to avoid examiner fatigue during the course of anatomical tracing and landmark marking needed for the study. These were performed over a period of ten days and then the cephalometric measurements were taken. A sheet of Ultraphan transparent tracing paper (3M Unitek,® Campinas, São Paulo, Brazil) measuring 8X10-in and 0.003-in thickness was placed over each tooth, and the tracings were performed using a mechanical pencil (Pentel,® São Paulo, Brazil) with 0.5 mm thick lead. Despite the existence of a large amount of detail that could be traced, only those structures that proved important to this study were reproduced. Left-side anatomical structures were drawn as they exhibit less distortion and also because the computer program (Dolphin Imaging® 11, Management Solutions, Chatsworth, CA) does not trace bilateral structures.

The cephalogram determined the contours of the following structures: Anterior limit of the frontal bone, frontonasal suture, nasal bones, orbit (with its posterior and inferior contours), mechanical porion, sella turcica, clivus, bony palate (traced from the anterior nasal spine to the posterior nasal spine), anterior contour of the maxilla, mandibular condyle, posterior border of mandibular ramus, lower border of mandibular body, anterior and posterior contours of the symphysis, upper and lower central incisors (which were more proclined), all drawn with the aid of a template (3M Unitek®, Campinas, Sao Paulo, Brazil), and soft tissue profile (Fig 1).

After completion of the cephalograms using the manual and digital methods the following cephalometric landmarks were traced as described by Araújo[2] and Ferreira[10] and illustrated in Figure 1.

- Point S (Sella); point N (Nasion); point ANS (Anterior Nasal Spine); point Po (Porion); point Or (Orbitale); point A (Subspinale); point B (Supramentale); point Pog (Pogonion); Point Me (Menton); point Go (Gonion); point Gn (Gnathion); point Co (Condylion); point Pn (Nose tip), Li (Lower lip); point Pog' (Soft Tissue Pogonion).

Once the landmarks had been traced, the lines and planes, depicted in Figure 1, could be obtained.

For this evaluation 14 measurements were selected, eight angles derived from the Tweed[26]

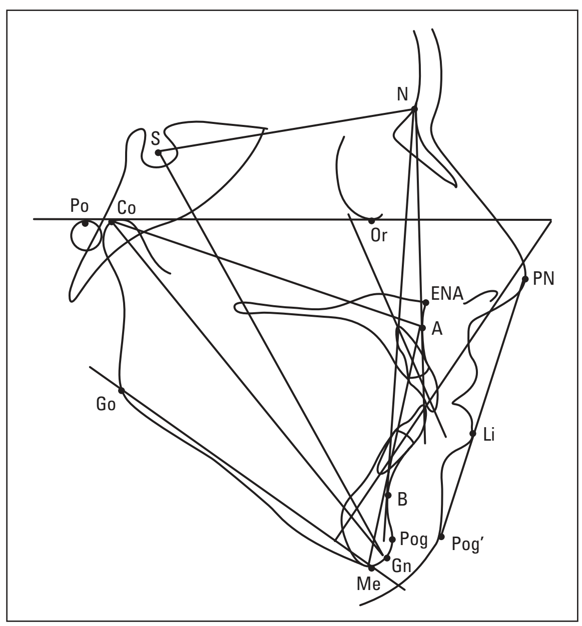

FIGURE 1 - Points and lines used in the study.

(FMA and IMPA); Steiner[23] (SNA, SNB, ANB, 1.NA, 1.NB) and Downs[9] (Y axis) analyses, and six linear measurements taken from the Steiner,[23] (1-NA, 1-NB); McNamara,[17] (Co-Gn, Co-A, LAFH) and Ricketts[20] (LE-Li) analysis.

After performing the tracings, the angular and linear measurements were obtained with the aid of a protractor (ref. 701-401) (3M Unitek®, Campinas, São Paulo, Brazil). The data were then tabulated for subsequent statistical analysis.

Digital methodology (Dolphin)

The 50 cephalometric radiographs were scanned into digital format using an HP Scanjet G4050 and exported to the Dolphin Imaging® 11.0 software (Dolphin Imaging and Management Solutions, Chatsworth, Calif.). An indicator was used (Dolphin® Radiographic Film Calibration Ruler) during image scanning to determine the amount of expansion and establish a proportion for the scanned images. The images were converted to JPEG format and saved with maximum quality with the Dolphin Imaging® 11.0 program. The file size of the final image was about 200Kb, with 200 dpi resolution. A 19" LCD 1550V flat screen monitor (Samsung®, São Paulo, Brazil) was used for viewing the images. When necessary, images were enhanced with brightness, contrast and magnification to identify areas with greater accuracy. The program illustrates all points and their tracing sequence, and allows users to magnify any specific areas.

In a first step, the researcher was properly calibrated by performing five sequential tracings until the technique was mastered. After calibration, 50 cephalometric tracings were performed using Dolphin Imaging® 11.0.

After scanning the radiographs and registering the patients a specific analysis, called MB analysis, was developed especially for use in this study. This analysis encompasses the following steps: 1) Selecting the cephalometric radiograph, 2) Clicking on the command "digitize", 3) Running the custom analysis editor, 4) Selecting the option "Single Analysis" to create a custom analysis (Fig 2) based on the linear and angular measures proposed by Tweed, Steiner, Downs, McNamara, Ricketts, as mentioned above.

The 42 cephalometric landmarks required by MB analysis were traced and digitized using Dolphin Imaging® 11.0 software.

Before implementing the digital tracings it was essential to determine the start and end points of the ruler (100 mm) with the purpose of rendering the actual size of each radiographic image (Fig 3).

The program illustrates all points and their tracing sequence, and allows users to magnify any specific areas (Fig 4).

By joining the above points the digital tracings were performed and linear and angular values obtained (Fig 5), which were accessed automatically by selecting the "Meas" (measures) button. Subsequently these values were treated statistically.

Statistical analysis

Data analysis

Evaluation of statistical differences between angular and linear measurements by the manual and digital methods was performed using Minitab software, version 14, and applying Student's t-test. Intraexaminer error was assessed by means of ten new, randomly selected tracings (five manual and five digital) after 20 days. The data obtained at T1 and T2 were compared using Student's t-test.

RESULTS

Intraexaminer error results showed no statistically significant difference at T1 and T2, as depicted in Tables 1 and 2.

Comparison of angular and linear measurements between the digital and manual groups is described in Tables 3 and 4.

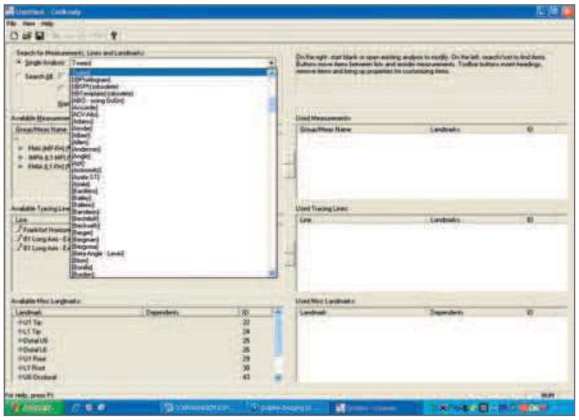

FIGURE 2 - Creating a custom analysis using the "Single Analysis" option.

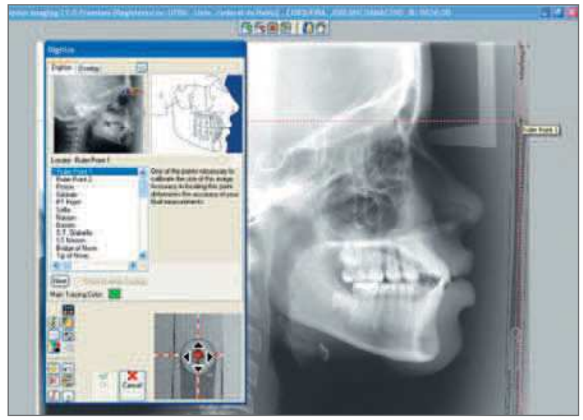

FIGURE 3 - Determining start and end points on the ruler (measurement standardization).

FIGURE 4 - Determining the points and performing the cephalometric tracing.

FIGURE 5 - Tracing and measurements generated by the program.

DISCUSSION

Cephalometry has contributed countless benefits to scientific research and the development of Orthodontics.

According to Albuquerque-Júnior and Almeida,[1] examiners can interfere significantly with systematic effects, affecting the reproducibility of cephalometric values. Silveira and Silveira[22] argue that one method to control errors in the replication of cephalometric measurements consists in calibrating examiners directly, and further suggest that such direct calibration be included in any scientific experiment. Tables 1 and 2 display a comparison between measurements taken by the examiner in manual and digital cephalometric tracings at different times (T1 and T2), showing that no statistically significant difference was found in any of the measurements in both groups.

These findings disagree with those of some authors[1,3,16,25] who claim that in cephalometry error is a constant even when examiners have extensive experience.

In this study, the analysis of the results obtained when comparing the angular and linear cephalometric measurements taken in digital and manual tracings revealed values that were very close to the means and standard deviations, reflecting a nonsignificant p value for all magnitudes (Tables 3 and 4). These findings support those of Chen[5], Correia et al[8] and Vasconcelos et al.[27] Conflicting results were found by other authors[6,13] whose data showed statistically significant differences, although accepted in clinical practice.

Researches shows a significant difference in measurements involving maxillary incisors,[25]

TABLE 1 - Comparison between the means and standard-deviations of linear and angular measurements obtained from manual tracings at T1 and T2.

Variables	Manual tracings (T1)	SD	Manual tracings (T2)	SD	p value
FMA	26.80	5.11	27.20	5.40	0.908
IMPA	95.40	4.67	95.20	4.21	0.945
SNA	83.00	5.29	83.00	4.69	1.000
SNB	77.50	3.87	77.90	3.29	0.865
ANB	5.50	2.69	5.10	2.92	0.828
1.NA	21.8	11.2	22.2	12.6	0.959
1.NB	28.20	7.92	29.60	8.73	0.798
Y Axis	59.70	2.39	60.60	1.52	0.503
1.NA	5.40	2.88	5.40	3.85	1.000
1.NB	6.80	3.47	6.60	3.21	0.927
Co-Gn	129.90	9.09	131.10	9.26	0.842
Co-A	102.10	1.67	102.40	2.07	0.808
LE-Li	1.50	3.64	1.30	3.75	0.934
LAFH	79.30	8.25	78.80	8.56	0.928

LE-Li = E Line-Lower lip.

TABLE 2 - Comparison between the means and standard-deviations of linear and angular measurements obtained from digital tracings at T1 and T2.

Variables	Digital tracings (T1)	SD	Digital tracings (T2)	SD	p value
FMA	27.3	5.17	26.88	5.61	0.88
IMPA	94.04	4.10	93.46	2.7	0.80
SNA	82.14	5.78	82.02	4.6	0.97
SNB	77.52	3.67	77.54	3.5	0.99
ANB	5.22	2.82	4.46	3.25	0.71
1.NA	20.76	11.12	21.34	13.4	0.94
1.NB	27.94	7.81	26.76	6.75	0.80
Y Axis	60.28	8.09	60.4	2.72	0.95
1-NA	5.82	3.27	6.72	4.6	0.73
1-NB	6.92	3.52	6.8	3.13	0.96
Co-Gn	130.38	8.91	130.66	9.72	0.96
Co-A	101.62	3.07	100.22	1.87	0.44
LE-Li	1.96	2.65	1.98	3.17	0.99
LAFH	80.04	8.09	60.4	7.96	0.92

(n.s.=non-significant, p>0.05).

TABLE 3 - Comparison between the means and standard-deviations of angular measurements obtained from manual and computerized tracings.

Variables	Manual mean (SD)	Dolphin mean (SD)	p value
FMA	27.46 (5.33)	27.59 (5.11)	0.90 n.s.
IMPA	96.27 (7.35)	95.50 (7.73)	0.61 n.s.
SNA	82.75 (3.63)	82.56 (3.61)	0.78 n.s.
SNB	78.75 (3.49)	78.55 (3.43)	0.77 n.s.
ANB	3.99 (2.86)	4.00 (2.84)	0.98 n.s.
1.NA	27.73 (8.91)	26.95 (8.90)	0.66 n.s.
1.NB	30.96 (7.20)	30.06 (7.66)	0.54 n.s.
Y Axis	59.57 (4.02)	60.15 (3.98)	0.47 n.s.

(n.s.=non-significant, p>0.05).

TABLE 4 - Comparison between the means and standard-deviations of linear measurements obtained from manual and computerized tracings.

Variables	Manual mean (SD)	Dolphin mean (SD)	p value
1.NA	8.23 (3.20)	8.02 (3.22)	0.74 n.s.
1.NB	7.97 (3.44)	7.91 (3.41)	0.92 n.s.
Co-Gn	125.37 (7.55)	125.09 (7.81)	0.85 n.s.
Co-A	96.29 (5.22)	95.68 (5.71)	0.57 n.s.
LAFH	74.11 (7.37)	74.45 (7.41)	0.81 n.s.
LE-Li	2.12 (3.76)	2.53 (3.56)	0.57 n.s.

(n.s.=non-significant, p>0.05).

mandibular incisors,[1] or both.[3,16] Brangeli et al[3] and Martins et al[16] argued that dental structures are difficult to locate and measurements of such structures have low reliability in both methods (manual and digital). In this study, the smallest p values were found in the Y-axis (p=0.47) and in incisor-related angular measurements (1.NB p=0.54, IMPA p=0.61; and 1.NA p=0.61), as shown in Table 3, but can still be considered reliable in both evaluation methods.

The lower reliability observed in the Y-axis angle was also found in a similar investigation conducted by Chen et al,[4] who encountered considerable difficulty in locating the point Gnathion.

It is a known fact that locating points on the apexes of incisors poses some serious difficulty in both radiographic film and scanned images. The latter can be even more challenging due to the presence of gray shades that merge in this region. Even when software features such as filtering and zooming are used, the task of locating these points is even more difficult than in X-ray films.[27] On the other hand, Albuquerque-Júnior and Almeida[1] and Chen et al[5] argue that the computerized method is reliable as it exhibits lower error variance than the conventional method. Forsyth et al,[11] however, in 1996, asserted that errors in the identification of points, angular and linear measurements tend to occur more often in digital images than in conventional radiography. Nonetheless, since no significant differences were found in this study, the authors consider the digital method sufficiently reliable for use in Orthodontics.

Assessment of the linear values obtained in digital and manual tracings (Table 4) showed that this comparison did not yield any significant differences. Lower p values can be observed in the Co-A (p=0.57) and LE-Li (p=0.57) measures. Collins et al[7] found statistically significant differences in linear measurements but these authors compared the Dolphin measurements of scanned and photographed images and found linear distortions in the latter.

This study found that the digital method is reliable, corroborating most authors[1,3,8,24,25,27] who compared different cephalometric tracing methods and programs and indicated its use in orthodontic practice.

Nowadays, digitizing X-rays has become the preferred method to perform cephalometric measurements. As technology evolves it becomes increasingly easier for professionals to adapt to the many routine tasks of clinical practice. This scientific investigation supports other studies published in the literature,[5,8,25,27] which confirm the enhanced effectiveness provided by today's technological resources.

This study evaluated the reliability of angular and linear measurements in manual and computerized cephalometric tracings performed with the aid of Dolphin Imaging® 11.0 software. However, further studies should be performed using this computer program since it features other tools for cephalometric tracing, such as overlays, predictive tracings for orthognathic surgery and profile manipulation, in addition to the options provided by the 3D program itself, which involves three dimensions.

CONCLUSIONS

According to the methods used in this study and the results achieved by comparing angular and linear measurements of manual and digital tracings it is reasonable to conclude that the cephalometric program Dolphin Imaging® 11.0 can be used reliably as an aid in diagnosing, planning, monitoring and evaluating orthodontic treatment both in clinical and research settings.

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