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Inter and Intra-rater Reliability of Lateral Cephalometric Analysis Using 2D Dolphin Imaging Software

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Objectives Cephalometric radiographs are widely used in diagnosis and treatment planning. In the past, these radiographs used to be analyzed manually, but nowadays due to the possibility of errors and time-consuming nature of manual tracing, digital methods are replacing the manual methods. The reliability of computer-assisted analysis is of great importance. The purpose of this study was to investigate the inter and intra-rater reliability of 2D Dolphin imaging software version 10.0.00.53.
Methods To assess the intra-rater reliability of lateral cephalometric analysis, 25 lateral cephalograms traced by one operator using Dolphin imaging software were traced again by the same examiner 2 weeks later. To assess the inter-rater reliability, 25 lateral cephalograms were traced independently by two examiners. Overall, 80 measurements including 43 linear, 34 angular, and 3 ratio measurements were made. The interclass correlation coefficient (ICC) was calculated to assess the inter-rater and intra-rater reliability. ICCs above 0.75 were considered good.
Results The ICC for intra-rater reliability was above 0.75 for all parameters except lower vertical height depth ratio (ICC=0.51), inter-labial gap (ICC=0.54), superior sulcus depth (ICC=0.67), articular angle (ICC=0.733), and ramus height (ICC=0.728). The ICC for inter-rater reliability was above 0.75 for all parameters except nose prominence (ICC=0.73).
Conclusion Dolphin imaging software showed good intra-rater reliability for most parameters and good inter-rater reliability for almost all parameters.
Keywords Cephalometry; Orthodontics; Reproducibility of Results; Digital Technology

Introduction

Cephalometric radiographs have been widely used for diagnosis, treatment planning, and evaluation of craniofacial problems, and have been an important tool in orthodontic procedures.[1, 2] In addition, lateral cephalograms are suitable to study facial profiles, which play an important role in profile esthetics.[3]

Manual cephalometric tracing was common in the past. In this method, the operator superimposes an acetate paper on the radiograph and marks the landmarks, lines, and angles on the cephalogram. In addition to the high probability of errors in identifying the landmarks and measurements, manual tracing is also a time-consuming procedure.[4, 5] Today, with the development of technology, various software programs have been developed to replace manual tracing.[6] Digital tracing has several advantages compared with manual tracing such as:

(I) the possibility of magnification and therefore more accurate identification of landmarks on low-quality radiographs.
(II) Easier editing
(III) Speeding up the analysis process
(IV) The possibility of creating an electronic file for the patient
(V) Easy access to patient's information
6) Enabling data comparison [5, 7, 8]

However, in many lateral cephalometric analysis programs, the process of landmark identification is still the responsibility of the examiner, and the possibility of errors in landmark identification still exists.[9]

Dolphin imaging software is a program that allows the operator to identify cephalometric landmarks on lateral cephalograms with a mouse on a screen. Then, the software performs the linear and angular measurements for the desired analysis by connecting the defined landmarks.[10]

Given the importance of landmark identification, and its impact on diagnosis and treatment planning, it is important to minimize measurement errors and have sufficient accuracy in identifying the appropriate location of landmarks. Reliability of measurements refers to achieving the same results when repeating the measurements.[11] The purpose of this study was to investigate the intra- and inter-rater reliability of 2D Dolphin imaging software version 10.0.00.53 (Dolphin Imaging and Management Solutions, Chatsworth, CA, USA) in identification of soft and hard tissue landmarks using the predefined analyses in the software.

Methods and Materials

Forty-seven digital lateral cephalometric radiographs, belonging to 23 males and 24 females, were randomly selected from the archives of Shahid Beheshti Dental School and six other dental clinics. All lateral cephalometric images had been taken with the Frankfort horizontal plane parallel to the ground, and the teeth in maximum intercuspation. The tongue was behind the maxillary incisors and the lips were at rest. The X-ray tube was at 1.5 m distance at a 90-degree angle relative to the patient's head. The film was placed at 30

cm distance from the patient's head. Cephalograms had been taken by two X-ray units (Pax-i 2D, Vatech, Hwaseong, Korea and Cranex, Soredex, Helsinki, Finland) with 80-90 kVp voltage and 6 and 18 seconds exposure time.

Patients with a symmetrical face, having all permanent teeth except third molars in those over 12 years, and no missing teeth in those under 12 years, and crowding or spacing < 6 mm were included. Patients with a history of systemic disease or trauma in the childhood affecting the developmental pattern were excluded.

Digital cephalograms were saved in JPEG format in their original quality. All lateral cephalograms were traced by a senior dental student using 2D Dolphin imaging software. A total of 43 linear, 34 angular, and 3 ratio measurements were made by 2D Dolphin imaging software as shown in Tables 1 and 2. Cephalometric landmarks used for these analyses are shown in Figure 1.

Inter-rater reliability: To assess the inter-rater reliability, 25 lateral cephalograms were traced by two calibrated examiners under the same environmental conditions independently. Both examiners were trained by an orthodontist before tracing.

The results of measurements made by each of the two operators were entered into Excel 2016 (Microsoft Corporation, Washington, USA).

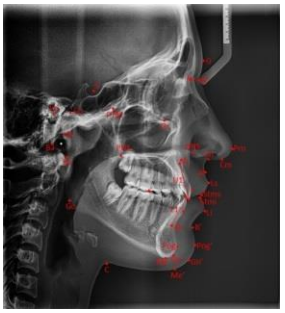

Figure 1- Cephalometric landmarks

Table 1- Intra and inter-rater reliability of the soft tissue cephalometric parameters using 2D Dolphin Imaging Software

Soft tissue cephalometric parameters	Intra Rater Reliability			Inter Rater Reliability		
	Two-way mixed	95% Confidence Interval		Two-way mixed	95% Confidence Interval	
		Lower	Upper		Lower	Upper
Facial convexity angle	0.973	0.94	0.988	0.966	0.925	0.985
Maxillary prognathism	0.854	0.697	0.933	0.945	0.879	0.975
Mandibular prognathism	0.885	0.757	0.948	0.959	0.908	0.982
Vertical height ratio	0.893	0.773	0.951	0.828	0.648	0.92
Lower facial throat angle	0.916	0.818	0.962	0.973	0.941	0.988
Lower vertical height–depth ratio	0.518	0.163	0.755	0.937	0.862	0.972
Nasolabial angle	0.899	0.784	0.954	0.887	0.761	0.949
Upper lip protrusion	0.942	0.873	0.974	0.887	0.76	0.948
Lower lip protrusion	0.989	0.975	0.995	0.937	0.862	0.972
Mentolabial sulcus depth	0.895	0.777	0.952	0.915	0.817	0.962
Vertical lip chin ratio	0.961	0.913	0.982	0.813	0.62	0.913
Maxillary incisor exposure	0.98	0.954	0.991	0.972	0.939	0.988
Interlabial gap	0.546	0.2	0.771	0.861	0.71	0.936
Soft tissue facial angle	0.957	0.905	0.981	0.954	0.898	0.979
H angle	0.985	0.966	0.993	0.963	0.919	0.984
Nose prominence	0.94	0.869	0.973	0.965	0.923	0.985
Superior sulcus depth	0.67	0.381	0.84	0.892	0.771	0.951
Soft tissue subnasale to H line	0.936	0.86	0.971	0.849	0.688	0.931
Skeletal profile convexity	0.945	0.88	0.976	0.947	0.884	0.976
Basic upper lip thickness	0.898	0.783	0.954	0.802	0.601	0.908
Upper lip strain measurement	0.966	0.924	0.985	0.916	0.82	0.962
Lower lip to H line	0.969	0.931	0.986	0.925	0.838	0.966
Inferior sulcus to H line	0.924	0.835	0.966	0.943	0.876	0.975
Soft tissue chin thickness	0.923	0.834	0.965	0.903	0.793	0.956
Lower lip to E-plane	0.983	0.962	0.993	0.971	0.935	0.987
Upper lip to E-plane	0.968	0.929	0.986	0.962	0.915	0.983
Upper lip length	0.965	0.922	0.984	0.827	0.647	0.92
Subnasale perpendicular to upper lip	0.895	0.776	0.952	0.875	0.737	0.943
Subnasale perpendicular to lower lip	0.977	0.949	0.99	0.86	0.709	0.936
Subnasale perpendicular to chin	0.972	0.937	0.987	0.968	0.929	0.986
Nasal tip protrusion	0.789	0.578	0.901	0.732	0.48	0.872
Nasal length	0.957	0.906	0.981	0.853	0.695	0.932
Nasofrontal angle	0.925	0.837	0.966	0.918	0.822	0.963
Nasal tip angle	0.838	0.667	0.925	0.853	0.695	0.932
Submental-Cervical angle	0.976	0.946	0.989	0.901	0.789	0.955
Lower lip vermilion height	0.964	0.92	0.984	0.927	0.842	0.967
Upper lip vermilion height	0.856	0.701	0.934	0.852	0.693	0.932
Lower lip thickness at vermilion border	0.89	0.767	0.95	0.855	0.699	0.934
The Z angle	0.982	0.96	0.992	0.974	0.942	0.988
Upper lip inclination to nasion-perpendicular	.906	.799	.958	0.914	.815	.961

Intra-rater reliability: To assess the intra-rater reliability of lateral cephalometric analyses, 25 lateral cephalograms traced by one examiner using Dolphin imaging software were again traced by the same examiner 2 weeks later under the same environmental conditions.

Statistical analysis:

SPSS version 26.0.0.1 (SPSS Inc., Chicago, Illinois, USA) was used for statistical analysis. The interclass correlation coefficient (ICC) with 95% confidence interval was used as the reliability coefficient. P<0.05 was considered significant. According to Torres et al, (12) ICC values higher than 0.70 and 0.90 were considered good and excellent, respectively.

Table 2- Intra and inter-rater reliability of the hard tissue parameters using 2D Dolphin Imaging Software

Hard tissue cephalometric parameters	Intra Rater Reliability			Inter Rater Reliability		
	Two-way mixed ICC	95% Confidence Interval		Two-way mixed ICC	95% Confidence Interval	
		Lower Bound	Upper Bound		Lower Bound	Upper Bound
SNA	0.913	0.813	0.961	0.901	0.788	0.955
SNB	0.954	0.899	0.980	0.939	0.866	0.973
ANB	0.938	0.865	0.972	0.906	0.799	0.957
Occlusal plane to SN angle	0.950	0.891	0.978	0.965	0.921	0.984
Mandibular plane angle	0.970	0.933	0.987	0.979	0.953	0.991
U1NA angle	0.914	0.816	0.961	0.920	0.827	0.964
U1NA distance	0.884	0.755	0.947	0.861	0.710	0.936
L1NB angle	0.884	0.756	0.947	0.767	0.539	0.890
L1NB distance	0.977	0.948	0.990	0.944	0.878	0.975
Inter-incisal angle	0.916	0.819	0.962	0.930	0.847	0.968
Nasion perpendicular to A point distance	0.875	0.738	0.943	0.902	0.790	0.956
Mandibular length	0.962	0.916	0.983	0.937	0.863	0.972
Maxillary length	0.935	0.859	0.971	0.875	0.737	0.943
Lower anterior face height	0.990	0.977	0.996	0.977	0.949	0.990
Facial axis angle	0.947	0.883	0.976	0.986	0.969	0.994
Pog to Nasion Perpendicular distance	0.958	0.906	0.981	0.937	0.862	0.972
Mandibular incisor position	0.980	0.956	0.991	0.882	0.751	0.946
Facial angle	0.956	0.903	0.980	0.938	0.864	0.972
Angle of convexity	0.946	0.881	0.976	0.946	0.882	0.976
Y axis angle	0.963	0.917	0.983	0.957	0.904	0.981
AB plane angle	0.943	0.875	0.975	0.867	0.722	0.939
Cant of occlusal plane	0.937	0.863	0.972	0.907	0.800	0.958
U1 to A-Pog line	0.981	0.957	0.992	0.946	0.882	0.976
Incisor occlusal plane angle	0.902	0.791	0.956	0.874	0.735	0.942
FMIA*	0.888	0.762	0..949	0.834	0.660	0.923
FMA**	0.968	0.928	0.986	0.967	0.926	0.985
IMPA***	0.917	0.820	0.962	0.876	0.738	0.943
Wits appraisal	0.977	0.949	0.990	0.899	0.784	0.954
Nasion angle	0.826	0.644	0.919	0.908	0.803	0.958
Saddle angle	0.922	0.831	0.965	0.933	0.855	0.970
Articular angle	0.733	0.483	0.873	0.793	0.584	0.903
Gonial angle	0.784	0.569	0.899	0.766	0.538	0.890
Chin angle	0.963	0.919	0.984	0.942	0.873	0.974
Anterior cranial base	0.938	0.864	0.972	0.851	0.692	0.932
Posterior cranial base	0.925	0.837	0.966	0.945	0.880	0.976
Ramus height	0.728	0.474	0.870	0.797	0.591	0.905
Anterior facial height	0.982	0.959	0.992	0.946	0.882	0.976
Posterior facial height	0.871	0.729	0.941	0.908	0.804	0.959
Mandibular corpus	0.930	0.847	0.968	0.903	0.792	0.956
Sum of angles (Jarabak)	0.972	0.938	0.988	0.972	0.938	0.988

Results

The ICC of measurements to evaluate inter- and intra-rater reliability is shown in Tables 1 and 2. P values of all measurements were less than 0.001.

Intra-rater reliability: Most measurements indicated acceptable ICC, which was above 0.75. Although lower vertical height depth ratio (ICC=0.51), inter-labial gap (ICC=0.54), superior sulcus depth (ICC=0.67), articular angle (ICC=0.733) and ramus height (ICC=0.728) showed unacceptable ICC values. The highest and the lowest ICC values belonged to lower anterior facial height (ICC=0.990) and lower vertical height depth ratio (ICC=0.518), respectively.

Inter-rater reliability: All measurements except nose prominence (ICC=0.73) showed acceptable ICC. The facial axis angle (ICC=0.986) showed the highest ICC.

Discussion

The purpose of this study was to investigate inter and intra-rater reliability of 2D Dolphin imaging software. According to the results, the inter-rater reliability was good for almost all values and the intra-rater reliability was good for most parameters. To date, various studies have compared the reliability of manual and digital lateral cephalometric tracing and also digital measurements made by different software programs.[13-15] Uysal et al. showed that the highest and the lowest inter-rater reliability correlation coefficients calculated for Dolphin imaging software 9.0 were for L1-NB distance (ICC=0.727) and Pog to Nasion perpendicular (ICC=0.449).[16] In our study, the inter-rater reliability correlation coefficients were excellent for both of these parameters (L1-NB: ICC=0.944, Pog to Nasion perpendicular: ICC=0.937). In our study, the highest and the lowest inter-rater reliability correlation coefficients belonged

to facial axis angle (ICC=0.986) and nose prominence (ICC=073), respectively, which were not analyzed by Uysal et al.[16] Uysal et al.[16] showed that the highest and the lowest intra-rater reliability correlation coefficients calculated for Dolphin imaging software were for lower lip to E plane distance (ICC=0.979) and nasolabial angle (ICC=0.578), respectively. Both of these parameters showed excellent correlation coefficients in our study (lower lip to E plane: ICC=0.983, nasolabial angle: ICC=0.899). In our study, the highest and the lowest intra-rater reliability correlation coefficients belonged to lower anterior facial height (ICC=0.990) and lower vertical height depth ratio (ICC=0.51), respectively. None of these parameters were analyzed by Uysal et al.[16]

Hand tracing is an old and standard method that has been extensively used in the past. But in addition to the fact that errors may occur in manual tracing, this process is very time-consuming. Computer-aided analysis is more accurate if the landmarks are identified correctly, and takes less time.[4, 5]

While Gravely et al.[17] believed that computer-aided analysis could not reduce the measurement errors compared with manual analysis, Chen et al.[18] showed that there was a difference between digital and manual tracing, although this difference was not clinically significant.

The difficulty in identification of some landmarks can be responsible for lower reliability of some measurements. Some studies have shown that identification of Gonion on lateral cephalograms can be challenging.[19-21] The low correlation coefficient for ramus height in our study may be due to this factor. Also, some studies have indicated that there might be significant errors in identification of Articular point.[4, 20, 21] This could explain the low correlation coefficient of articular angle. Several studies have shown that the locations assigned to Po and Or points can be variable. [9, 21, 22] Thus, measurements based on the Frankfort horizontal plane might be erroneous and this justifies the low reliability of nose prominence and superior sulcus depth. Low correlation coefficient of lower vertical height depth ratio might be due to the difficulty in identification of C point caused by the wide variations in the location of this landmark. Inter-labial gap is the distance between Stms and Stmi points. The error in determining these two landmarks might be due to their proximity on lateral cephalograms of many individuals.

Torres et al.[12] showed that the time spent on analysis might affect the accuracy of landmark identification process. Also, Chen et al. [18] indicated that this matter is highly dependent on the operator's experience. In the present study, both examiners were well trained, had the same level of experience, and the time used by both was approximately equal and around 9.6 minutes for each cephalogram.

Due to the effect of different parameters on the relationship of teeth with teeth, teeth with jaws, jaws with the cranial base, and the inter-maxillary relationship, it is desirable to perform several analyses to investigate these parameters. In the present study, 43 linear measurements, 34 angular measurements, and 3 ratio measurements were made using the Legan and Burstone[23], Holdaway[24], Epker[25], Ricketts [26], Z Merrifield [27], Steiner[28], McNamara[29], Tweed[30], Bjork[31], Jarabak, Downs[32] and some supplementary analyses[33-36] on 47 lateral cephalograms to investigate the inter- and intra-rater reliability of Dolphin imaging software.

Conclusion

According to our study, lateral cephalometric analysis using 2D Dolphin software can be considered as a reliable method. The results revealed that the inter-rater reliability was good for almost all values, and the intra-rater reliability was good for most parameters. Considering the results of our study, some landmarks are difficult to identify and should be identified more accurately.

Conflict of Interest

No Conflict of Interest Declared■

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