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Lateral Cephalogram from CBCT Reliable Approach for Orthodontic Diagnosis: - a Comparative Study

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Abstract

Aim: With the increased use of cone beam computed tomography (CBCT) scans in orthodontic diagnosis and treatment planning, validation of using radiographic images obtained from CBCT instead of multiple conventional radiographs is needed. Hence, the present study was designed to assess the differences between cephalometric measurements taken from manual tracings (MT), digitized lateral cephalograms (DLC) and CBCT lateral cephalograms scans
Methods: Conventional lateral cephalograms and CBCT scans from ten subjects from departmental archives were used to assess the three methods: manual tracings, digitized lateral cephalograms, and CBCT lateral cephalograms. Seventeen measurements were evaluated and retraced after a 7-day period. The intra examiner errors was assessed using the paired t test and Dahlberg formula. The Pearson correlation test and ANOVA test evaluated the differences between the methods.
Results: Most of the measurements had intra-examiner reliability in all three methods. Measurements were significant among methods were Y-axis, U1-Apog (degree and mm), U1-NA, L1-NB (degree and mm), L1-Apog, and interincisal angle.
Conclusion: All three methods proved to be reliable and reproducible with minimum error in the measurement of lateral cephalograms. The CBCT scan, advised for complex cases, can be used to generate lateral cephalogram images, which may reduce the need for multiple radiographs, thereby reducing radiation exposure and cost.

Keywords: Cone-beam computed tomography, Diagnosis, Lateral cephalogram,

1. Background

Cephalometry plays a vital part in diagnosis, treatment planning, and aids in assessing the growth and development of the stomatognathic system. In earlier years, manual lateral cephalogram tracing was commonly used for cephalmetric analysis but they are being replaced by technological advancements, such as digital tarcing. However, until now, lateral cephalograms taken from CBCT scans have not been scientifically compared, thus not popularly use in diagnosing and treatment planning. Hence, it is prudent to validate the images obtained from these advanced techniques compared against conventional radiographs.

Several studies have compared manual and digital lateral cephalograms but the results have been unsatisfactory because of the greater possibility of errors when determining landmarks, or during hand tracing and measurements. Several studies (1,2,3,4) have evaluated manual tracing and measurement with digitized cephalograms, wherein tracing and measurements were obtained by imaging software, and a few researchers have concluded that the digital method is more accurate in linear and angular measurements than the manual method.

Still, there is no consensus regarding transition from manual tracing to digital tracing among orthodontists. As the world is moving towards digitization and advancement, it is imperative to understand and adapt to newer technology (5) for better treatment planning and outcomes. However, the latest technology needs to be studied and evaluated in depth before it can be advocated for routine use. Thus, the aim of this study was to assess the differences between cephalometric measurements taken from manual tracings (MT), digitized lateral cephalograms (DLC), and lateral cephalograms generated from CBCT scans (CBCT-LC).

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2. Methods

The protocol of the study was approved by the Institutional ethics committee. It was a retrospective study, wherein ten patients' conventional DLCs and CBCT scans were obtained from archives and their CBCT scans were referred to for detailed diagnosis and treatment planning. Cephalometric analysis was done on each lateral cephalogram image along with CBCT-LCs. For the manual tracings, the cephalograms were traced manually and assessed as per standard method. For the DLCs, the measurements were done using the Dolphin Imaging software (Version 11.95, Dolphin Imaging, Chatsworth, CA, USA), and the same software was used for cephalometric measurements for the CBCT-LCs. Seventeen measurements were used for comparison (Table 1). The lateral cephalograms were obtained from the same Kodak Carestream CS 3000 machine (17.6 s., 77 kVp), with the subjects situated at a distance of 1.52 m from the cephalostat. Standard protocols were used to obtain the measurements. Then they were retraced after seven days by the same examiner to assess intra-examiner reliability.

For the MTs, the measurements were obtained in a darkened room, with lead acetate paper (size: 8"x10"), set square and lead pencil. For the DLC, the same 10 patients' digital images were digitized with the Dolphin software and measurements were recorded. CBCT scans were done with a Kodak Carestream CS9300 (FOV of 20x15 cm, 40 s, 0.4 voxel, 90 kVp, and 15 m ss) the landmarks were confirmed and the measurements produced automatically by the software.

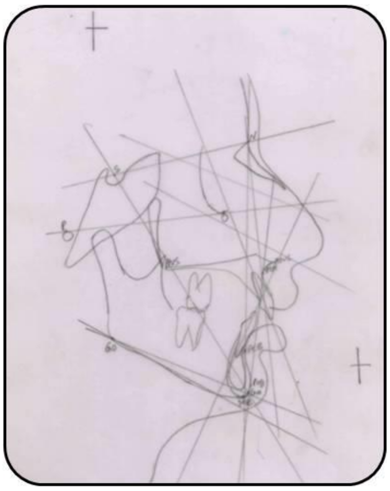

Figure 1. Landmarks traced manually from DLC

Figure 2. Landmarks traced digitally from DLC

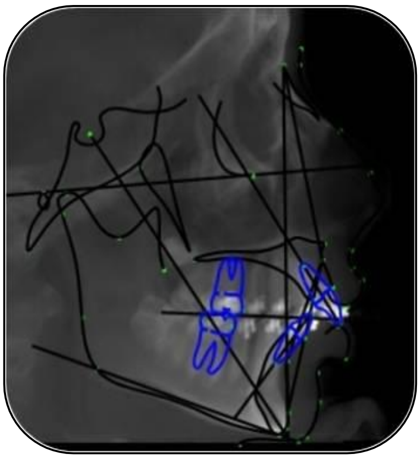

Figure 3. Landmarks traced digitally using LC-CBCT

After the 7-day period of the initial measurement (T1), all the images were retraced by the identical evaluator to procure the next measurement (T2). The error of the method was assessed by the paired t test and the Dahlberg formula.

Statistical analysis

A mean value and standard deviation was calculated all the measurements. Analysis of variance (ANOVA) along with Tukey tests were used for comparison between different methods. Statistical analysis was performed with SPSS software (Version 22).

3. Results

Systematic errors were not seen in any variables in all three groups with p<0.05. The range of casual errors for MT differed from 0.47 to 1.52, 0.16 to 0.59 for the DLC and 0.30 to 0.61 in the LC-CBCT group, as obtained by the Dahlberg formula (Tables 2, 3, and 4).

Table 1. Cephalometric variables used for measurements

SNA	Angle formed by Sella, Nasion, and point A
SNB	Angle formed by Sella, Nasion, and point B
ANB	Angle formed by point A, Nasion, and point B
Interincisal Angle	Angle formed by long axis of upper and lower central incisors
IMPA	Angle formed by long axis of lower central incisors with mandibular plane
U1 - SN (º)	Angle formed by long axis of upper central incisors with SN plane
U1 - NA (º)	Angle formed by long axis of upper central incisors with line connecting Nasion and point A
L1 - NB (º)	Angle formed by long axis of lower central incisors with line connecting Nasion and point B
Y AXIS	Angle formed by SN plane with line connecting Sella and Gnathion
SN - GoGn (º)	Angle formed by SN plane with line connecting Gonion and Gnathion
FMA (º)	Angle formed by FH plane with mandibular plane
U-Incisor Inclination (U1-Apo)	Angle formed by long axis of upper central incisors with line connecting point A and Pogonion
L1 to A-Po (º)	Angle formed by long axis of lower central incisors with line connecting point A and Pogonion
L1 - NB(mm)	Linear distance measured by most labial surfaces of lower central incisors with the line connecting point B and Nasion
U1 - NA (mm)	Linear distance measured by most labial surface of upper central incisors with the line connecting point A and Nasion
U-Incisor Protrusion (U1-APo) (mm)	Linear distance measured by most labial surfaces of upper central incisors with the line connecting point A and Pogonion
L1 Protrusion (L1-APo) (mm)	Linear distance measured by most labial surfaces of lower central incisors with the line connecting point A and Pogonion

Table 2. Results of systematic and casual errors in the study for manual tracing

	1st Measurement		2nd Measurement		Correlation Coefficient (r)	P Value <0.05	Dahlberg
	Mean	SD	Mean	SD			
SNA	82.67	4.75	85.87	4.60	0.74	<0.001	0.47
SNB	76.17	5.35	76.12	5.29	0.98	0.892	0.59
ANB	6.5	2.15	7.92	2.04	0.77	0.036	0.65
Interincisal Angle	126.25	9.16	125.95	9.09	0.98	0.912	1.01
IMPA	97.33	7.01	97.12	6.88	0.95	0.786	1.37
U1 - SN (º)	101.17	8.95	101.70	8.61	0.91	0.834	1.22
U1 - NA (º)	19.5	7.01	20.45	8.52	0.83	0.061	1.43
L1 - NB (º)	25.29	5.84	26.5	5.85	0.97	0.078	1.21
Y AXIS	64.83	7.05	66.04	62.34	0.96	0.553	1.52
SN – Go Gn (º)	26.92	9.19	28.20	9.23	0.99	0.745	1.09
FMA (º)	23.83	8.1	24.62	8.23	0.99	0.568	0.96
U-Incisor Inclination (U1-Apo)	31.75	4.55	32.29	6.97	0.95	0.026	1.11
L1 to A-Po (º)	21.75	4.20	22.79	5.95	0.73	0.052	1.44
L1 - NB (mm)	5.17	2.40	5.75	2.22	0.96	0.654	0.61
U1 - NA (mm)	3.83	2.11	3.95	1.78	0.94	<0.001	0.49
U-Incisor Protrusion (U1-APo) (mm)	5.63	2.97	7.29	2.84	0.79	0.058	0.66
L1 Protrusion (L1-APo) (mm)	0.5	2.43	0.79	2.87	0.91	0.158	0.73

Table 3. Results of systematic and casual errors in the study of digital tracings

	1st Measurement		2nd Measurement		Correlation Coefficient (r)	P Value <0.05	Dahlberg
	Mean	SD	Mean	SD			
SNA	84.22	5.24	85.35	4.92	0.94	0.079	0.46
SNB	77.70	5.78	77.85	5.53	0.96	0.281	0.41
ANB	6.52	1.76	7.84	1.67	0.91	0.043	0.53
Interincisal Angle	125.07	8.98	125.6	9.21	0.95	0.832	0.59
IMPA	97.79	8.28	98.09	8.59	0.99	0.734	0.57
U1 - SN (º)	105.59	9.08	105.63	9.01	0.99	0.789	0.36
U1 - NA (º)	20.95	5.95	21.27	6.28	0.99	0.543	0.52
L1 - NB (º)	24.04	6.79	24.40	6.68	0.99	0.678	0.46
Y AXIS	59.74	3.86	59.88	4.05	0.98	0.890	0.45
SN - GoGn (º)	26.35	9.40	26.48	9.27	0.99	0.643	0.46
FMA (º)	22.35	7.11	22.45	6.98	0.99	0.328	0.46
U-Incisor Inclination (U1-Apo)	34.22	5.24	34.28	5.18	0.99	0.543	0.47
L1 to A-Po (º)	19.38	5.29	19.75	5.34	0.99	0.512	0.35
L1 - NB (mm)	4.35	6.00	4.78	6.01	0.99	0.892	0.38
U1 - NA (mm)	1.87	2.21	1.93	2.54	0.98	0.674	0.37
U-Incisor Protrusion (U1-APo) (mm)	5.19	2.67	5.30	2.70	0.99	0.765	0.16
L1 Protrusion (L1-APo) (mm)	-0.54	1.41	-0.7	1.55	0.98	0.542	0.21

Table 4. Results of systematic and casual errors in the study of LC-CBCT tracings

	1st Measurement		2nd Measurement		Correlation Coefficient (r)	P Value <0.05	Dahlberg
	Mean	SD	Mean	SD			
SNA	82.81	4.11	83.23	4.19	0.97	0.765	0.46
SNB	75.88	5.11	76.07	5.14	0.99	0.435	0.30
ANB	6.91	2.45	7.12	2.42	0.98	0.673	0.36
Interincisal Angle	129.71	10.13	129.99	10.17	0.99	0.576	0.60
IMPA	98.02	6.93	98.17	6.91	0.93	0.211	0.52
U1 - SN (º)	100.34	10.08	100.35	9.90	0.91	0.897	0.58
U1 - NA (º)	17.45	7.18	17.78	6.76	0.97	0.342	0.54
L1 - NB (º)	24	5.66	24.02	5.65	0.89	0.332	0.50
Y AXIS	55.78	11.20	56.10	11.00	0.98	0.543	0.51
SN - GoGn (º)	27.84	9.79	27.84	9.84	0.97	0.657	0.53
FMA (º)	21.87	7.67	21.81	7.86	0.92	0.832	0.56
U-Incisor Inclination (U1-Apo)	31.9	6.93	32.02	6.91	0.94	0.789	0.48
L1 to A-Po (º)	18.52	4.59	19.16	4.57	0.95	0.431	0.55
L1 - NB (mm)	1.41	0.90	1.9	0.93	0.84	0.337	0.36
U1 - NA (mm)	0.48	0.66	0.62	1.13	0.87	0.569	0.44
U-Incisor Protrusion (U1-APo) (mm)	2.13	0.91	2.39	1.11	0.89	0.430	0.39
L1 Protrusion (L1-APo) (mm)	0.00	1.167	-0.15	1.34	0.94	0.721	0.33

Pearson correlation analysis was significant among three methods studied (Table 5). However, a weak positive correlation existed among measurements related to upper and lower incisors. The difference in all measurements for the three groups were statistically insignificant except for the Y-axis, U1-Apog, U1-NA, L1-NB, L1-Apog, and interincisal angle (Table 6).

Table 5. Correlations between methods (Pearson correlations)

Group	Digital vs CBCT1		Digital vs Manual		CBCT1 vs Manual	
	r	p	r	p	r	p
SNA	0.799	0.002	0.871	<0.001	0.833	0.001
SNB	0.88	<0.001	0.929	<0.001	0.888	<0.001
ANB	0.945	<0.001	0.954	<0.001	0.884	<0.001
Interincisal Angle	0.947	<0.001	0.885	<0.001	0.894	<0.001
IMPA	0.899	<0.001	0.931	<0.001	0.957	<0.001
U1 - SN (º)	0.8	0.002	0.741	0.006	0.868	<0.001
U1 - NA (º)	0.652	0.022	0.629	0.028	0.761	0.004
L1 - NB (º)	0.819	0.001	0.932	<0.001	0.852	<0.001
Y AXIS	0.811	0.077	0.84	0.001	0.972	0.012
SN - GoGn (º)	0.928	<0.001	0.965	<0.001	0.976	<0.001
FMA (º)	0.914	<0.001	0.941	<0.001	0.905	<0.001
U-Incisor Inclination (U1-Apo)	0.66	0.02	0.516	0.086	0.733	0.007
L1 to A-Po (º)	0.72	0.008	0.822	0.001	0.626	0.03
L1 - NB (mm)	0.665	0.043	0.767	0.024	0.744	0.106
U1 - NA (mm)	0.657	0.02	0.611	0.035	0.108	0.737
U-Incisor Protrusion (U1-APo) (mm)	0.23	0.472	0.842	0.001	0.312	0.323
L1 Protrusion (L1-APo) (mm)	0.759	0.004	0.38	0.223	00.15.442	

Table 6. Intergroup comparisons of the cephalometric variables among the three methods evaluated (ANOVA and Tukey tests)

Group	Digital		CBCT 1		Manual		P Value
	Mean	Std. Deviation	Mean	Std. Deviation	Mean	Std. Deviation	
SNA	84.38*	5.08	83.02	4.15	82.77*	4.67	0.149
SNB	77.78*#	5.65	75.97*	5.13	76.14#	5.31	0.055
ANB	6.68	1.68	7.02	2.43	6.70	2.06	0.0559
Interincisal Angle	125.33*	9.10	129.85*#	10.14	126.10#	9.10	0.003
IMPA	97.94	8.43	98.1	6.92	97.22	6.88	0.326
U1 - SN (º)	105.61*#	9.05	100.35*	9.99	101.43#	8.74	0.05
U1 - NA (º)	21.11	6.12	17.61	6.97	19.97	7.02	0.126
L1 - NB (º)	24.22*	6.73	24.01	5.65	25.89*	5.81	0.048
Y AXIS	59.80*	3.95	55.94#	11.10	65.43*#	6.65	0.003
SN - GoGn (º)	26.41	9.33	27.84	9.81	27.56	9.21	0.342
FMA (º)	22.40*	7.05	21.84#	7.76	24.22*#	8.15	0.085
U-Incisor Inclination (U1-Apo)	34.25	5.20	31.96	6.92	32.02	4.70	0.293
L1 to A-Po (º)	19.57*	5.32	18.84#	4.58	22.27*#	4.29	0.018
L1 - NB (mm)	4.56	6.01	1.658*	0.91	5.45*	2.29	0.001
U1 - NA (mm)	1.90*	2.37	0.55*	0.87	3.89*	1.93	0.001
U-Incisor Protrusion (U1-APo) (mm)	5.25*	2.69	2.26*#	0.99	5.95#	2.89	0.004
L1 Protrusion (L1-APo) (mm)	-0.62	1.48	-0.075	1.24	0.64	2.61	0.14

4. Discussion

The technical differences between conventional lateral cephalograms and CBCTs reflects variations in the cephalometric measurement. The distance between the midsagittal plane of the head, radiation source, and film being fixed in cephalostat. However, in the CBCT device, the source moves around the patient as with the orthopantomogram, possibly resulting in magnification error with no effect on angular measurements but affecting linear values.

The principal goal of this study was to assess the reproducibility of the parameters taken from the three types of cephalograms. Based on the analyses, the measurements obtained were not dependent on the kind of image used. The cephalometric analyses done on CBCT cephalograms had greater reproducibility compared to the measurements taken from the conventional and the digital cephalograms (Table 2, 3, and 4). Projection errors are usually seen with conventional cephalograms that produce inaccurate results especially for bilateral landmarks, which could result in poor reproducibility in the MT and DLC groups when compared with LC-CBCT.

Nearly all the measurements had a statistically significant difference in the MT group, with greater prominence on landmarks including point A such as SNA, ANB, U1-NA, U1-Apog, L1-Apog. This could be because of the difficulty in locating A point, Porion and so forth (6). Moreover, manual errors are a result of the drawing of lines while tracing landmarks by hand (4). However, majority of the measurements were significant in the DLC and LC-CBCT group. At the same time, radiographic film can store data for many years but it is not a perfect and secure way to archive the data (7,8). Hence, as the quality of film is lost with time, it is advisable to archive all data in digital format.

Magnification of radiographs are often done to identify certain important structures more accurately and precise (9). However, this results in the blurring of images, making identification of landmarks difficult. A higher scanning DPI helps in overcoming this problem, therefore 400 DPI images were used in this study.

The LC-CBCT measurements did not indicate much significant difference in T1 (first measurement) and T2 (second measurement). Previous studies (7,8) have mentioned that the grading errors are linked to landmark identification that depend on various factors such as experience of the examiner, quality of image and so forth. Dolphin software has the feature to enhance the quality of cephalograms, making it practical particularly when marking soft tissue landmarks. For some of the variables, the Pearson's correlation analysis proved significant among the three methods studied. Moreover, most measurements indicated a high correlation and these near results are in agreement with a study done by Grauer (8) et al.

Manual tracing and digital tracing for the image obtained by CBCT or digital lateral cephalogram shows some significant differences for some of the variables (Table 6). However, finding the cephalometric landmarks becomes easier by using advanced tools that make the contrast between anatomic structures clearer and identifiable. The direct method to identify landmarks on the computer screen has many advantages that include excellent repeatability and reproducibility, are efficient as no tracing is needed and no need of hard copies of the digital images (10,11).

The parameters used for cephalometric analysis in this study mostly comprises of hard tissue and dental variables from routinely used cephalometric analysis. Soft tissue variables are not included due to the difference in contrast and image formation. The CBCT data of any patient allows the possibility of unlimited reformatting of images with interactive adjustment. Furthermore, bilateral structures of the skull can be separated thereby preventing overlapping of these structures.

However, the CBCT images are only considered necessary when 3D anatomy is important for diagnosis and treatment planning (12) as CBCT results in a higher radiation dose than traditional radiographs along with high cost. Therefore, CBCT can be recommended as a routine diagnostic aid when multiple radiographs are needed for planning treatment as radiation exposure from one CBCT scan is comparable when the patient is exposed to multiple radiographs such as for an impacted tooth, or those with facial asymmetries or craniofacial anomalies, or TMJ problems, in which CBCT is more capable of appraising the dissimilarities between the right and the left side of craniofacial structures.

Conclusion

All three methods proved to be reliable and reproducible, with minimum error in the measurements of CBCT–LC. CBCT scan advised for complex cases to generate lateral cephalogram images that will reduce the need for multiple radiographs; thereby reducing the radiation exposure and cost.

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