ORIGINAL ARTICLE

A comparative cephalometric analysis between conventional and CBCT generated lateral cephalograms

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background and aims: Cone-beam computed tomography (CBCT) is becoming established as a superior radiographic technique to conventional radiography in orthodontics. However cephalometric analysis in conventional lateral cephalograms (LC) is still an important tool in treatment planning. The aim of this study was to compare cephalometric measurements performed on conventional cephalograms with those on CBCT generated images.

Method and materials: 24 patients with both LC and volumetric CBCT imaging (Newtom 3G) were selected. Generated Lateral cephalograms (GLC) were produced from related DICOM files in Dolphin 3D. cephalometric analysis, consisted of fifteen angular measurements and fifteen linear measurements (Dolphin V.11.2) were performed on both LCs and GLCs. Paired T-Test was used to compare differences in measurements between the two image modalities.

Results: According to paired t-test results no statistically significant differences were found between the two set of measurements except Articular Angle, Gonial Angle (Ar-Go-Me) and Ramus Height (Ar-Go) ($P<0.05$). Since in all cases the interval between LC and CBCT imaging was short (3.5 months ± 2) and treatment has began after CBCT imaging, neither growth nor treatment was the cause of these differences. It could be supposed that the technical positioning errors in LCs of some patients might be the cause.

Conclusions: LC could successfully be replaced by GLC. Since we can select the best orientation of the skull before generating GLC from CBCT DICOM files, GLC could be more reliable than LC.

Keywords: Cone-beam computed tomography (CBCT), Imaging, Three-Dimensional,Orthodontics

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INTRODUCTION

Radiographic imaging is an important diagnostic adjunct in the assessment of skeletal and dental relationships for the orthodontic patient. Cephalometric analyses are performed to determine deviations in the skeletal and dentoalveolar relationship by identifying specific landmarks on both hard and soft tissues to consecutively calculate the spatial and angular relationship between them.

Three-dimensional imaging techniques are becoming increasingly popular and have opened new possibilities for orthodontic diagnosis and treatment assessment. Despite the usefulness of computed tomography (CT), the high cost and relatively high radiation exposure make this modality unsuitable for orthodontic purposes.[1]

Recently, cone-beam computed tomography (CBCT) systems have been developed specifically for the maxillofacial region and it has many applications[2,3]. The clinical value proposition of CBCT is to describe craniofacial anatomy accurately and provide comprehensive information regarding anatomical relationships and individual patient findings for improved diagnosis, treatment planning and prognostication.[2] 2D images, including panoramic, lateral, and postero-anterior views, could be generated from 3D CBCT volume images[2] but dose requirements were suggested to be more than other dental radiographic modalities in present use[4,5] so we should not cone beam all our starts.[6] Maxillofacial applications of CBCT have been used for patients that need maxillofacial surgery and patients with impacted teeth or any kinds of asymmetry[7] but the lack of 3D standard population norms has restricted CBCT from routine orthodontic use. Cephalograms have been used in orthodontic treatment planning and outcomes assessments for 75 years. Over this time, a substantial database of information linking 2D standardized head radiographs to orthodontic treatment outcomes has been collected. As the orthodontic specialty moves toward the use of a 3-dimensional (3D) cephalometric paradigm, it seems illogical to discard the valuable information from the past. There might well be a value to be able to reconstruct classical cephalograms from a CBCT data set without the need to unnecessarily reradiate the patient. According to past studies the overall landmark identification errors on CBCT-derived cephalograms were comparable to those on conventional digital cephalograms.[8] The aims of this study was to test the difference between cephalometric measurements of CBCT-generated cephalograms with measurements of conventional cephalograms in the same patients.

MATERIAL AND METHODS

Twenty-four patients were originally included in this study. The inclusion criteria were that each patient had both a conventional cephalogram and a 12-in CBCT scan (NewTom 3G) available within a 6-month period. The axial images were imported in Dolphin 3D (v. 11.2). A 3D virtual model was created from the original file and carefully oriented according to Frankfort and infraorbital plane. Using axial, coronal, and sagittal views, the midsagittal plane of the model was oriented vertically; the infraorbital and the Frankfort plane were oriented horizontally. (Fig 1)

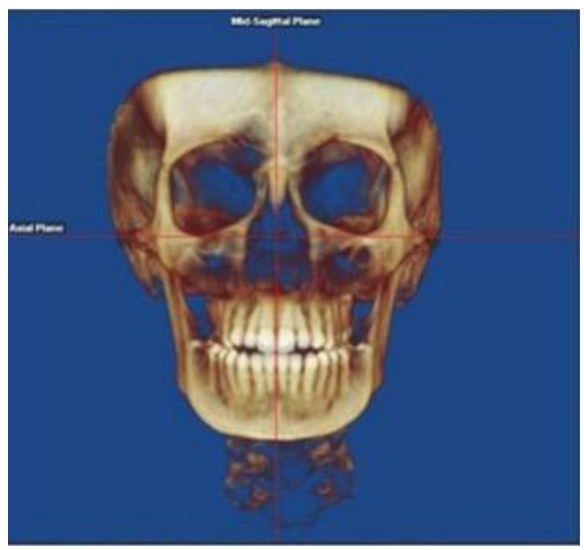

Fig.1. Orientation of the three-dimensional virtual model to generate the cephalograms.

Then lateral cephalograms was generated simulating the geometry of the conventional cephalometric radiographs with 9% magnification (same as conventional cephalometric radiographs according to the manufacturer's instructions). (Fig 2)

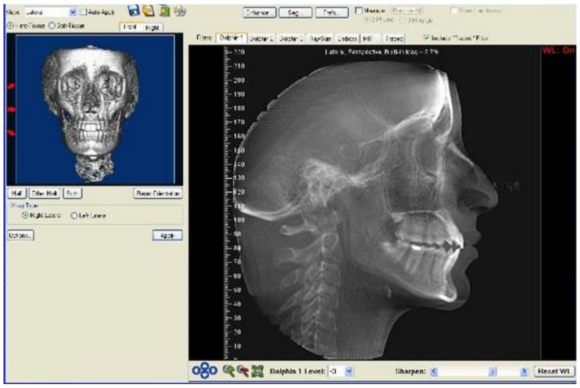

Fig.2. CBCT-derived lateral cephalogram

Dolphin imaging software (v. 11.2) was used for cephalometric tracings for both CBCT-derived and conventional cephalograms. (Fig 3)

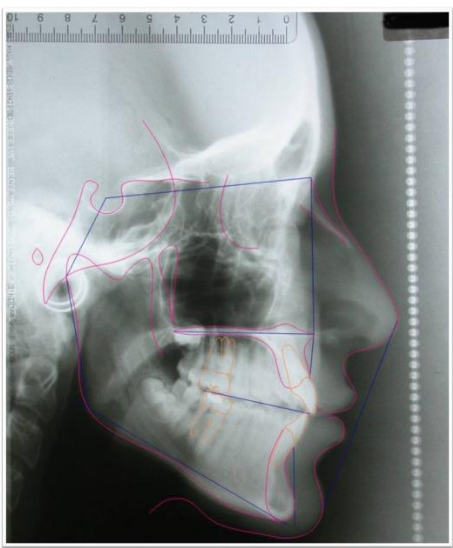

Fig. 3. Anatomic landmarks and planes used in analysis superimposed on conventional lateral cephalometric image

Fifteen linear and fifteen angular variables based on soft- and hard-tissue landmarks were measured (Table 1,2). The measurements were selected to include both vertical and anteroposterior components of the craniofacial form. The landmarks on which these measurements were based represented both midsagittal and bilateral anatomic structures. The measurements carried out by a single operator in a randomized fashion and repeated another time with 2 monthsdelay.

Tabel 1. Angular (°)variables used in this study

1)	Saddle/Sella Angle (SN-Ar) (º)
2)	Articular Angle (º)
3)	Gonial/Jaw Angle (Ar-Go-Me) (º)
4)	Palatal-Mand Angle (PP-MP) (º)
5)	SNA (º)
6)	SNB (º)
7)	ANB (º)
8)	U1 - Palatal Plane/Mx Base (º)
9)	Interincisal Angle (U1-L1) (º)
10)	SN - MP (º)
11)	FMA (MP-FH) (º)
12)	U1 - SN (º)
13)	L1 - MP (º)
14)	IMPA (L1-MP) (º)
15)	FMIA (L1-FH) (º)

Tabel 2. Linear (mm) variables used in this study

1)	Anterior Cranial Base (SN) (mm)
2)	Posterior Cranial Base (S-Ar) (mm)
3)	Ramus Height (Ar-Go) (mm)
4)	Length of Mand Base (Go-Pg)(mm)
5)	Upper Face Height (N-ANS) (mm)
6)	Lower Face Height (ANS-Gn) (mm)
7)	Total Face Height (N-Gn) (mm)
8)	Wits Appraisal (mm)
9)	U1 - NA (mm)
10)	Lower Lip to E-Plane (mm)
11)	Upper Lip to E-Plane (mm)
12)	Lower Lip to E-Plane (mm)
13)	Upper Lip to E-Plane (mm)
14)	Pog - NB (mm)
15)	Posterior Face Height (SGo) (mm)

Statistical Analysis

The statistical analyses were performed by Microsoft Excel 2010. Dahlberg formula was used to assess intraobserver differences and Paired T-Test was used to compare differences in measurements between the two image modalities.

RESULTS

According to Dahlberg formula the meausrement error between two times of tracing was 0.49-2.53 for conventional lateral cephalograms and 0.32-2.6 for CBCT-generated cephalograms and reliability of the cephalometric measurements for both image modalities were acceptable.

According to paired t-test results no statistically significant differences were found between the two set of measurements except Articular Angle, Gonial Angle (Ar-Go-Me) and Ramus Height (Ar-Go) ($P<0.05$) (Table 3)

Table 3. Mean and SD of Angular and Linear measurements from the 2 imaging techniques with P values of the T-test between them

Variables	Conventional Lat.Ceph.		CBCT Generated Lat.Ceph.		Paired t-test
	Mean	SD	Mean	SD	p value
Saddle/Sella Angle (SN-Ar) (º)	122.82	5.75	123.01	5.94	0.75
Articular Angle (º)	146.48	7.74	143.73	6.65	0.02
Gonial/Jaw Angle (Ar-Go-Me) (º	131.74	6.22	134.93	5.98	0.00
Anterior Cranial Base (SN) (mm)	72.31	4.29	71.96	4.27	0.08
Posterior Cranial Base (S-Ar) (mm)	33.53	3.59	33.33	3.03	0.65
Ramus Height (Ar-Go) (mm)	44.04	4.25	45.80	5.11	0.02
Length of Mand Base (Go-Pg)(mm)	74.65	5.68	75.22	5.37	0.40
Upper Face Height (N-ANS) (mm)	54.00	3.96	54.08	3.35	0.88
Lower Face Height (ANS-Gn) (mm)	72.46	5.55	73.33	5.43	0.06
Total Face Height (N-Gn) (mm)	125.44	7.61	126.56	7.01	0.07
Palatal-Mand Angle (PP-MP) (º)	30.98	6.49	31.31	6.22	0.50
SNA (º)	78.65	3.79	79.00	3.66	0.41
SNB (º)	75.08	4.67	75.27	4.82	0.50
ANB (º)	3.57	2.75	3.74	2.44	0.63
U1 - Palatal Plane/Mx Base (º)	110.50	7.47	110.38	7.09	0.90
Interincisal Angle (U1-L1) (º)	130.64	9.19	129.98	8.75	0.46
Wits Appraisal (mm)	0.28	4.43	0.25	3.72	0.96
SN - MP (º)	35.93	7.13	36.01	6.96	0.88
FMA (MP-FH) (º)	28.42	6.57	26.86	6.21	0.07
U1 - NA (mm)	4.20	2.61	4.52	2.58	0.46
U1 - SN (º)	100.63	8.78	100.04	8.37	0.45
L1 - MP (º)	90.58	5.66	91.66	5.58	0.08
Lower Lip to E-Plane (mm)	-1.08	3.13	-1.51	2.39	0.47
Upper Lip to E-Plane (mm)	-3.84	2.64	-4.35	2.34	0.08
IMPA (L1-MP) (º)	87.90	5.95	88.32	5.17	0.40
FMIA (L1-FH) (º)	61.01	7.04	61.48	5.99	0.53
Lower Lip to E-Plane (mm)	-1.08	3.13	-1.51	2.39	0.47
Upper Lip to E-Plane (mm)	-3.84	2.64	-4.35	2.34	0.08
Pog - NB (mm)	1.24	2.48	1.29	2.30	0.81
Posterior Face Height (SGo) (mm)	73.94	5.26	74.85	6.07	0.07

DISCUSSION

Lateral cephalograms and orthopantamograph together with facial photographs are currently the main diagnostic imaging modalities used in the assessment of orthodontic problems. However, the use of 2D views in the analysis of 3D objects can cause overlapping of structures and lead to landmark identification errors[9,10], which has in turn led to a search for new techniques. CT and CBCT modalities that have come into use over the past decade have been found to overcome the limitations associated with traditional cephalometric analysis. The high radiation dose to which patients are exposed led to questions regarding the necessity of CT examination. CBCT have been used for orthodontic patients but the lack of 3D standard population norms has restricted CBCT from routine orthodontic use. For using database of information linking 2D standardized head radiographs to orthodontic treatment outcomes the cephalometric measurements performed on CBCT-synthesized cephalogramsshould should be compatible with measurements on conventional cephalograms.

According to this study cephalometric measurements performed on CBCT-synthesized cephalograms of patients are comparable with measurements on conventional cephalogramsexcept three measurements: Articular Angle, Gonial Angle (Ar-Go-Me), Ramus Height (Ar-Go).

Since in all cases the interval between conventional lateral cephalogram and CBCT imaging was short (3.5 months ± 2) and treatment has began after CBCT imaging, neither growth nor treatment was the cause of the statistically significant differences between the two imaging modalities for Articular Angle, Gonial Angle (Ar-Go-Me), Ramus Height (Ar-Go).

CBCT image could be taken as the gold standard. In contrast to conventional cephalograms, the errors due to malposition of the patient during image acquisition could be corrected in CBCT data sets by iterative adjustment. The first issue might be because errors of projection present in the conventional cephalograms, and therefore the identification of landmarks of bilateral structures (e.g. the mandibular line) presents some inaccuracy[9]. In all of this measurements Ar (Junction of the posterior ramus plane and the superstructure of the temporal bone) and Gonion are involved. Both landmarks are bilateral landmarks and it the technical positioning errors in conventional lateral cephalograms of some patients might be the cause of some differences in these measurements. Incorrect head posture during cephalometric radiography may produce right-left inaccuracies and leads to these measurement differences.

Ar landmark was defined more posteriorly in CBCT-generated cephalograms and this produces smaller Articular angle, larger gonial angle and longer ramus height in CBCT-generated cephalograms relative to conventional lateral cephalograms.

Previous in-vitro studies, performed on dry skulls demonstrated no difference between cephalometric measurements performed on CBCT-generated cephalograms and conventional cephalometric analyses.[11,12] More accurate positioning of dry skull in cephalometric machine may cause prevention of this error during invitro studies.

CONCLUSIONS

- CBCT cephalometric image reconstruction can be recommended as an alternative to conventional cephalograms when a CBCT volume is already available, thus reducing the need for additional x-ray exposure and expense

- Since we can select the best orientation of the skull before generating CBCT-synthesized cephalograms, CBCT-generated cephalograms could be more reliable than conventional lateral cephalogram

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