ORIGINAL ARTICLE

A COMPARATIVE STUDY OF DIGITAL LATERAL CEPHALOGRAM AND VIRTUAL CONE-BEAM COMPUTED ASSISTED CEPHALOGRAM IN CEPHALOMETRIC ANALYSIS

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Background: The Advent of innovative technologies like Cone Beam Computed Tomography (CBCT) scans presents itself as an alternative to traditional lateral cephalometric radiography. However, it is imperative to validate images generated using this technology for meaningful comparisons. Moreover, emphasizing the necessity to justify the amount of radiation exposure is crucial. Through this investigation, we seek to determine the comparability of angular and linear measurements derived from Digital lateral cephalometry and CBCT derived lateral cephalograms. **Methods:** Forty lateral cephalometric radiographs and 40 virtual cephalograms from cone-beam computed tomography were analyzed, involving forty patients from the Orthodontic Department at Fauji Foundation Hospital Islamabad. After the prior calibration, two sets of measurements were taken within a fifteen-day interval using Down's analysis and WebCeph software. The discrepancies between these measurements were assessed to determine their significance. **Results:** There was strong correlation between the measurements of 2D and 3D cephalometric angles among FA, AOC, MPA, YA, COP, IIA, IOPA, IMPA and UIAP Linear. The most notable variance was observed in the Cant of occlusal plane (COP) reaching a statistical significance ($p<0.05$). Conversely, Y-axis exhibited the least variance. **Conclusions:** The absence of statistically significant differences suggests that, in our study, choice of radiograph used for analysis had minimal impact on the cephalometric measurements. These findings highlight the reliability and comparability between CBCAC and DLC.

Keywords: Dental Occlusion; Cone-Beam Computed Tomography; Cephalometry; Radiation Exposure; Artificial intelligence

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INTRODUCTION

Digital lateral cephalogram (DLC) has been used over a long time as one of the main diagnostic tools used for investigations and treatment-planning in the field of orthodontics. It has also been considered a reliable method for assessment of craniofacial growth.[1]

Despite the popularity, it is widely known for the errors in image projection or landmark identification.[2,3] These errors give rise to fault in cephalometric tracings[4] attributing to magnification errors, superimposition of landmarks and distorted images.

The Advent of innovative technologies like Cone Beam Computed Tomography (CBCT) scans presents itself as an alternative to traditional lateral cephalometric radiography. CBCT scans offer a variety of images, including panoramic renderings, PA views, and lateral cephalometric views. However, it is imperative to validate images generated using this technology for meaningful comparisons. Emphasizing the necessity to justify the amount of radiation exposure is crucial. Hence, if a comprehensive clinical examination deems it necessary to obtain a CBCT scan, as in the cases of cleft lip and palate or impacted tooth, obtaining 2D cephalogram from the same scan will not only result in decreased radiation exposure, but will also save patient the cost of additional radiograph.

As of now, there is a limited number of studies documenting normative cephalometric values derived from 3D data sources.[5,6] Hence, the aim of this study is to assess the disparities in cephalometric measurements between lateral cephalograms obtained from CBCT and digital lateral cephalograms. Through this investigation, we seek to determine the comparability of angular and linear measurements derived from 3D and 2D techniques.

A universally accepted gold standard radiograph for cephalometric evaluation is yet to be established.[7] Conventional imaging methods are under scrutiny due to increased likelihood of errors in landmark identification and measurements obtained by hand tracing, as well as the considerable time required for cephalometric analysis. Additionally, the limitations of 2-dimensional diagnosis, such as anatomic superposition, are noteworthy.[8] In recent times, use of digital software for cephalometric analysis has garnered popularity due to the fact, it has effectively reduced many manual tracing-related errors. Furthermore, it enables to conduct multiple analyses in a short timeframe[9] offering other benefits, such as improved landmark identification, amplification of image and better data storage[10,11]. A program called WebCeph, powered by two-dimensional (2D) artificial intelligence, operates on both computers and as a mobile application. It permits both digital and manual landmark identification with the automatic calculation of measurements and various cephalometric analysis with great accuracy.[12] Our study utilizes the same programme for digitization and analysis of radiographs.

Given that there has not been much data on comparisons between DLC and virtual cone-beam computed assisted cephalogram (CBCAC), the use of these images in comparison to lateral cephalograms is questionable, making it crucial to ensure the reliability and accuracy of these images in orthodontic evaluations. The conversion of 3D image into 2D, as seen in cephalometric analysis, raises concerns about a potential decrease in accuracy. It remains uncertain whether this difference holds clinical significance.[9] Through this investigation, we seek to determine the comparability of angular and linear measurements derived from DLC and CBCAC.

MATERIAL AND METHODS

This study utilized a cross-sectional research design to investigate the differences in cephalometric measurements between Digital Lateral Cephalogram (DLC) and Cone Beam Computed Assisted Cephalograms (CBCAC). It was conducted at the Department of Orthodontics, Foundation University College of Dentistry and Hospital (FUCD&H) and ethical approval was obtained prior to data collection from the institute's ethical review committee.

A sample size of eighty radiographs (40 DLC and 40 CBCAC) was determined based on previous research investigating the reliability and reproducibility of digital cephalometric analysis. Inclusion criteria involved patients aged 13 to 30 years with high-quality radiographs, while images with artifacts were excluded. Any potential radiographic errors that could skew study outcomes were rectified. Digital images were stored using the Romexis computer database.

Down's analysis served as the primary method for measurement and assessment in this research due to its comprehensive coverage of major dentoskeletal landmarks while utilizing a limited number of variables. Nine variables, comprising eight angular and one linear measurement, were examined. In group 1, forty cephalometric radiographs were chosen that were performed on MYRAY Hyperion X5. All the radiographs were obtained while the Frankfurt plane was maintained parallel to the floor to position the patient, while rods were employed to stabilize the head and prevent any movement.

In group 2 forty CBCT scans were selected that were initially performed on Planmeca ProMax® 3D Classic. The head of the patient was positioned naturally, with the closed mouth posture and teeth aligned in their usual and natural bite position. They were instructed to maintain stillness throughout the procedure. Selection of radiographs was random, from the pre-treatment records of patients undergoing orthodontic treatment at the Department of Orthodontics, FUCD&H.

To obtain CBCAC, a lateral image was obtained from the overall CBCT volume, ensuring alignment with the Frankfurt plane parallel to the floor. Volume positioning was achieved using cursor control, followed by selection of the save option upon attaining the desired alignment. The software then automatically generated a lateral image in JPEG format. Contrast and brightness adjustments were applied to optimize visualization and aid in identifying anatomical landmarks.

Using the WebCeph Version: 1.0.0, Google Chrome Ver. 84.0.4149.125 software program, the primary investigator identified dentoskeletal landmarks and digitally performed anatomic tracings for both type of radiographs (CBCAC and DLC) (Figure 1 & 2). While digitization, the software highlights the starting and ending points, with the option for precise adjustments to the landmarks and consequently alters the lines and curvatures, allowing for convenient movement. Upon completion, the software offers multiple analysis. The Downs analysis was chosen, encompassing both angular and linear parameters. Once the analysis was selected, the software automatically generated measurements, and the data for each analysis was exported in PDF format. Comparisons were made between the measurements obtained from both types of radiographs.

A sole operator conducted all cephalometric studies to minimize potential biases and errors, thereby ensuring the consistency of measurements and enhancing the reliability of the gathered data. To ensure the consistency and reliability of anatomical landmark assessment and measurements, same investigator utilized the WebCeph software program to digitally perform anatomic tracings on ten randomly selected radiographs of both DLC and CBCAC types.

The radiographs were employed for the study without explicit consent, as they were archival imaging records from previous examinations. This retrospective study utilized existing imaging data, for which consent for both undergoing the imaging procedure and potential research usage had been previously secured. Digital images were stored using the Romexis computer database, version 3.6.0, by Planmeca in Helsinki, Finland.

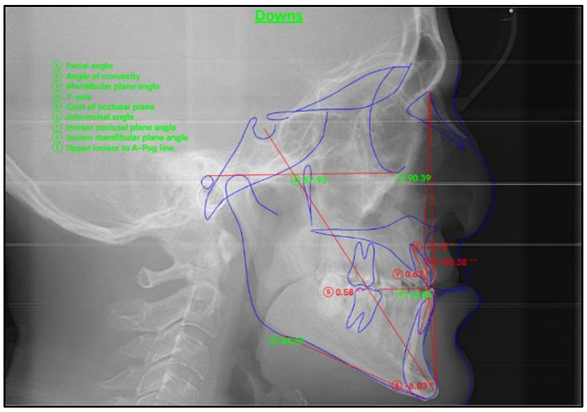

Figure-1: Digital Lateral Cephalogram showing digital cephalometric analysis using WebCeph

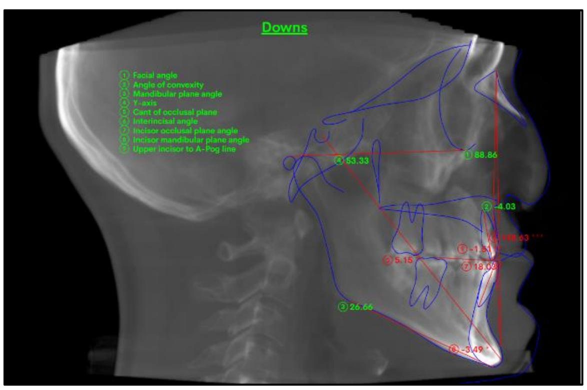

Figure-2: CBCT assisted lateral Cephalogram showing cephalometric analysis using WebCeph

Data analysis was conducted utilizing the SPSS software. The normal distribution of continuous data within our investigation was evaluated through the Shapiro-Wilk test. The angular and linear measurements from the DLC and CBCAC sets were analyzed. Results indicated that COP and UIAP had normal distributions, while FA, AOC, MPA, YA, IIA, IOPA, and IMPA showed non-normal distributions. Consequently, the significance levels for these variables were assessed using the Mann-Whitney U test, with degree of freedom maintained at 80 as shown in Table-4. Upon confirming the absence of a normal distribution for the two variables, the decision was made to examine the variances between measurements utilizing the Mann-Whitney U test. Comparison of mean values for the measured variables between DLC and CBCAC was performed utilizing an independent sample t-test. The significance threshold was established at 0.05, accompanied by a confidence interval of 95%. A *p*-value of 0.05 or lower was deemed statistically significant, denoting a noteworthy distinction between the two radiographic techniques.

Table-1: Down's Analysis

Variable	Definition
Facial Angle (FA)	Angle between FH-Plane and N-Pog line
Angle Of Convexity (AOC)	Angle between N-A-Pog
Mandibular plane angle (MPA)	Angle between Mandibular plane and FH plane
Y-Axis (YA)	Angle between S-Go and FH-Plane
Cant Of Occlusal Plane (COP)	Angle between Occlusal plane and FH-Plane
Interincisal Angle (IIA)	Angle between long axis of upper and lower incisors
Incisal Occlusal Plane Angle (IOPA)	Angle between long axis of lower incisor and occlusal plane
Incisor Mandibular Plane Angle (IMPA)	Angle between long axis of lower incisor and mandibular plane
Upper Incisor-A-Pog (UIAP)	Linear distance between upper incisor and A-Pog line

RESULTS

The correlation between measurements of 2D and 3D cephalometric angles was strong among majority of the variables including FA 88.31±4.38 (0.751), AOC 1.02±10.17 (0.413), MPA 28.14±4.83 (0.210), YA57.73±4.30 (0.988), COP 2.37±3.29 (0.000), IIA 150.14±10.36 (0.193), IOPA19.92±7.42 (0.531), IMPA -4.67±5.62 (0.654) and UIAP -3.24±2.61 (0.916) Linear as shown in Table 3. The most notable variance was observed in the Cant of occlusal plane (COP) reaching a statistical significance (*p*=0.000). Conversely, Y-axis exhibited the least variance (*p*=0.988). The absence of statistically significant differences suggests that, in our study, choice of radiograph used for analysis had minimal impact on the cephalometric measurements. These findings highlight the reliability and comparability between CBCAC and DLC. The Shapiro-Wilk test was used to check the normality of the data distribution for all cephalometric variables in the study. Results indicated that COP and UIAP had normal distributions, while FA, AOC, MPA, YA, IIA, IOPA, and IMPA showed non-normal distributions. Consequently, the significance levels for these variables were assessed using the Mann-Whitney U test, with degree of freedom maintained at 80 as shown in Table 4.

Table-2: Group statistics of Group 1 (DLC) and Group 2 (CBCAC) for all the variables

Variables	Group	Mean ±*SD*	Std. Error Mean
Facial Angle (FA)	DLC	88.45±21	0.71542
	CBCAC	88.17± 3.72	0.6796
Angle Of Convexity (AOC)	DLC	2.05 ± 10.80	1.50480
	CBCAC	-0.002± 10.80	1.70871
Mandibular plane angle (MPA)	DLC	28.27 ±3.65	0.57778
	CBCAC	28.01± 5.83	0.92235
Y-Axis (YA)	DLC	57.67 ±4.42	0.69961
	CBCAC	57.78± 4.24	0.67059
Cant of Occlusal Plane (COP)	DLC	0.76 ±3.37	0.53343
	CBCAC	3.98± 2.28	0.36195
Interincisal Angle (IIA)	DLC	147.39± 13.08	2.06918
	CBCAC	152.89± 5.54	0.87694
Incisal Occlusal Plane Angle (IOPA)	DLC	20.72 ±9.24	1.46168
	CBCAC	19.13 ±4.99	0.78920
Incisor Mandibular Plane Angle (IMPA)	DLC	-4.94± 5.94	0.94017
	CBCAC	-4.39± 5.34	0.84493
Upper Incisor-A-Pog (UIAP)	DLC	-3.03 ±3.03	0.47937
	CBCAC	-3.44±2.13	0.33688

Table-3: Comparison of Group 1 (DLC) and Group 2 (CBCAC) with respect to the assessment of measurements of various parameters

Variable	Mean±SD	*p*-Value
Facial Angle (FA)	88.31±4.38	0.751
Angle Of Convexity (AOC)	1.02±10.17	0.413
Mandibular plane angle (MPA)	28.14±4.83	0.210
Y-Axis (YA)	57.73±4.30	0.988
Cant Of Occlusal Plane (COP)	2.37±3.29	0.000*
Interincisal Angle (IIA)	150.14±10.36	0.193
Incisal Occlusal Plane Angle (IOPA)	19.92±7.42	0.531
Incisor Mandibular Plane Angle (IMPA)	-4.67±5.62	0.654
Upper Incisor-A-Pog (UIAP)	-3.24±2.61	0.916

(Significance $*p \leq 0.05$)

Table-4: Normality test results of data

Variable	Statistic	Significance
Facial Angle (FA)	.958	.010*
Angle Of Convexity (AOC)	.939	.001*
Mandibular plane angle (MPA)	.911	.000*
Y-Axis (YA)	.912	.000*
Cant Of Occlusal Plane (COP)	.971	.067
Interincisal Angle (IIA)	.935	.001*
Incisal Occlusal Plane Angle (IOPA)	.829	.000*
Incisor Mandibular Plane Angle (IMPA)	.955	.007*
Upper Incisor-A-Pog (UIAP)	.980	.231

DISCUSSION

Computed tomography is becoming increasingly integrated into orthodontic practice as a primary diagnostic tool. The utilization of three-dimensional data is anticipated to witness a significant surge, potentially supplanting numerous traditional orthodontic record-keeping methods currently in use.[13] Radiation exposure and costs have notably decreased, while the diagnostic efficacy substantially surpasses that of conventional radiographic techniques.[14] Nonetheless, the utilization of three-dimensional data presents fresh challenges, requiring a departure from conventional methods of static image interpretation to fully exploit the available capabilities. Cephalometric assessments can now be conducted by digitizing points in three-dimensional coordinates. A crucial initial step towards establishing cone-beam computed tomography (CBCT) imaging as a standard orthodontic diagnostic procedure involves evaluating the accuracy of landmark identification, routinely utilized in orthodontic diagnosis.

Our study aimed to compare the precision and dependability of cephalometric analysis employing CBCAC with conventional DLC, which serve as the benchmark for cephalometric analysis. We assessed angular and linear measurements, as outlined in Down's analysis, utilizing WebCeph software.

The measurements of both 2D and 3D cephalometric angles exhibited a high correlation, yet notable statistically significant differences were observed in Cant of occlusal plane (COP) measurements ($p<0.05$) when comparing the two-dimensional and three-dimensional approaches. However, measurements of FA, AOC, MPA, YA, IIA, IOPA, IMPA, and UIAP Linear demonstrated no statistical variance between 2D and 3D analyses.

Our findings offer reassurance that the disparities between 2D and 3D data are minimal in significance. Although statistically significant differences were detected between a singular modality, a thorough examination of each metric is warranted to ascertain whether and when these disparities might bear clinical relevance. Significant distinctions between 2D and 3D cephalometric measurements were observed particularly in the Cant of occlusal plane (COP). This parameter exhibited a statistically notable contrast, albeit its impact on treatment efficacy appears limited. The dissimilarities between 2D and 3D measurements for COP may stem from various factors, including the presence of irregular dental alignment among subjects in the database, as well as the susceptibility of teeth cusps to measurement inaccuracies due to superimpositions. Dental reference points typically exhibit lower validity compared to skeletal ones.[15] Notably, among skeletal reference points, point A displays greater variability owing to its anatomical location and wider variation.[16] However, our study demonstrates reliable reproducibility of angles encompassing point A, such as AOC and UIAP.

The findings of this study align with several others that have compared conventional cephalograms with CBCAC revealing satisfactory reproducibility for both modalities. For instance, similar inference was drawn by Jesica Calle- Morocho and Rafael Morales-Vadillo. They concluded that the discrepancy between the two image types is minimal, thereby affirming the effectiveness of both evaluation methods. They assessed forty virtual lateral cephalograms obtained from CBCT against 40 lateral cephalograms analyzed via Steiner's analysis.[17]

John B. Ludlow and Maritzabel Gubler found results that were contradictory to ours. They determined that the multiplanar displays of CBCT volume images offer more precise identification of traditional cephalometric landmarks compared to conventional methods. Specifically, they found improved accuracy in locating condylion, gonion, and orbitale, addressing the issue of overlapping bilateral landmarks observed in traditional cephalometry.[18]

Rebeca Menezes *et al*. conducted a study to assess the precision and dependability of two-dimensional craniometric landmarks derived from CBCT reconstructions. This investigation demonstrated the feasibility of establishing reference points from 3D models which is in line with the findings of our study.[19]

An interesting finding by Navarro et al concerned reproducibility of CBCAC. The study compared digital, manual and CBCAC in their research. Their findings indicated that the analyses conducted on CBCAC exhibited greater reproducibility than both digital and conventional cephalograms.[20]

Wen *et al*. suggested that if the 3D images can be simply converted into 2D format for analysis, additional exposure is unnecessary. They highlighted two significant aspects regarding CBCT-generated cephalograms. Firstly, they underscored the benefit of cephalograms as an alternative to standard lateral radiography, particularly for patients who have already undergone CBCT scans, thus reducing radiation exposure and radiography expenses. Secondly, they noted the limitation that cephalograms might not offer additional value for every orthodontic case.[21]

The field of cephalometric analysis is currently experiencing a paradigm shift as it transitions from traditional 2D radiographic evaluation of the craniofacial skeleton to advanced 3D analysis. Angular cephalometric measurements obtained from a DLC are comparable to those derived from a 3D source. Moreover, the conversion of DLC from CBCAC for ease of clinical workflow raises concerns regarding the potential loss of clinically relevant information.[22]

The study's constraints involve the subjective identification of landmarks, a challenging task even with digital software in 3D settings.[23] Landmarks that are challenging to identify include the gnathion, orbitale and the posterior point of the condylion, gonion and anterior nasal spine as they may be obscured by overlapping structures. Achieving precise landmark identification is crucial, particularly when employing novel tools in scientific inquiry, as inaccuracies in image interpretation could lead to erroneous diagnoses and treatment plans. Therefore, future efforts should focus on refining this aspect, including updates to free of cost versions of digital softwares for enhanced anatomical point detection in 3D-rendered lateral cephalograms.

CONCLUSIONS

The use of CBCT technology for lateral cephalometry in orthodontics is both valid and reliable. When a patient requires a CBCT scan after a comprehensive clinical evaluation, additional images can be extracted from it, including lateral cephalometric analysis, reducing the need for separate radiographic procedures and minimizing patient exposure. Integrating 3D technology alongside traditional cephalometry enhances daily clinical practice.

AUTHORS' CONTRIBUTION

MQ: Literature search, data collection, write-up. RN: Conceptualization of study design, data analysis, data interpretation, proof reading.

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