Available Online at http://www.recentscientific.com
CODEN: IJRSFP (USA)
International Journal of Recent Scientific Research
Vol. 8, Issue, 8, pp. 19212-19219, August, 2017
ISSN: 0976-3031
International Journal of Recent Scientific Research
DOI: 10.24327/IJRSR

Research Article

ACCURACY & RELIABILTY OF MANDIBULAR MEASUREMENTS ON LATERAL CEPHALOGRAMS & CBCT SCANS

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DOI: http://dx.doi.org/10.24327/ijrsr.2017.0808.0649

ARTICLE INFO

Article History:

Received 15th May, 2017
Received in revised form 25th June, 2017
Accepted 23rd July, 2017
Published online 28th August, 2017

Key Words:

Cephalometry; CBCT, Accuracy, Reliabilty, Digital tracing, on screen digitization

ABSTRACT

The aim of this study was to compare the accuracy and reliability of mandibular cephalometric measurements on conventional 2D lateral cephalograms and 3D CBCT scans from same 30 subjects into three groups: Group I manual tracings for 2Dlateral cephalogram, Group II On screen digitized 2D lateral cephalograms and Group III digital tracing for CBCT derived 3D lateral cephalograms. Nineteen mandibular cephalometric parameters (12 angular and 7 linear) were assessed. ANOVA and Post HOC-LSD test was applied and statistical analysis revealed nonsignificant difference between Group I & Group II. However, significant difference was found between 2D conventional lateral cephalograms and Digital tracing for CBCT derived 3D lateral cephalograms for four angular (GoG-SN, FMA, S-Ar-Go, IMPA) & one linear parameter r(Co-Gn). The results demonstrated that all evaluated methodologies are reliable and valid for scientific research, the method used in the lateral cephalograms from the CBCT proved the more accurate and reliable.

INTRODUCTION

Cephalometry is an essential clinical and research tool in orthodontics used to describe the morphology and growth of craniofacial skeleton, growth prediction, treatment planning and evaluate treatment results. After the advent of radiographic machines in the early 1900s, Broadbent[1] first captured the imagination of orthodontic specialists, and since then it has been used for decades to obtain absolute and relative measures of the craniofacial skeleton.[2-3]. Moyers *et al*[4] defined Cephalometry as a radiographic technique for abstracting the human head into a measurable geometric scheme. Cephalometric measurements have several drawbacks, including errors that are classified as either ''Errors of projection'' which result in distortion and differential magnification of the craniofacial complex or ''Errors of identification'' and reduced measurement accuracy as lateral cephalograms are two-dimensional (2D) radiographs that are used to depict three dimensional (3D) structures[5-7].

Bilateral landmarks and structures usually give a dual image on the radiograph. Misalignment of the cephalostat and rotation of the patient's head in the cephalostat in any plane can also induce errors of projection.[8]

New technological advances in craniofacial imaging have been able to solve these problems and are becoming increasingly popular for use in orthodontic diagnosis and treatment planning. Cone beam Computed Tomography (CBCT) is a technique that has been proposed for maxillofacial imaging during the last decade and was first reported on by Mozzo *et al*.[9]
A new generation of compact CT scanners has been developed specifically for imaging the head and neck region.[10] These scanners use a cone beam geometry which allows for better efficiency in X-ray photon utilization.[11] Increasing access to CBCT imaging for orthodontics are enabling the movement from 2D cephalometric analysis to 3D analysis. The replacement of conventional cephalograms with CBCT for the assessment of craniofacial relationships has the potential to be a significant step forward in the diagnosis and treatment of selected orthodontic and surgical patients.

The gold standard method for cephalometric evaluation has not been identified yet. Despite the widespread use of manual tracing technique in orthodontics - the technique is time-consuming and has several drawbacks, including a high risk of error in tracing, landmark identification, and measurement. In computerized cephalometric analysis, once the requested landmarks have been entered, the software automatically

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calculates distances and angles, thus eliminating errors that may occur in manual tracing when drawing lines with a ruler and measuring angles with a protractor. Also computer-assisted cephalometrics is less time-consuming than manual tracing, and it allows the user to obtain several analysis at a time with no problem of film deterioration. Enhancement of on-screen quality by adjusting the contrast, grey scale, and accentuate the edges of structures has been found to improve the on-screen visibility of the landmarks. However, landmark identification of 3D structure over a 2D image still remained a drawback. To overcome this CBCT derived cephalometric measurements might be of help.

Since an existing database with standard population norms is not available for the 3D CBCT volume, patients for whom the CBCT data are acquired may be subjected to further radiation exposure for the acquisition of traditional lateral cephalograms so that traditional cephalometric tracing may be done. The comparison of traditional lateral cephalometric measurements with those of digital images and those obtained from CBCT scans becomes necessary with a view to make a change from 2 dimensional to 3 dimensional method.

Thus, to evaluate the accuracy & reliability of various angular and linear mandibular measurements on 2D conventional lateral cephalograms & 3D CBCT scans, the present study was undertaken to determinewhether difference exists between cephalometric measurements- based on manual tracing of 2D conventional lateral cephalograms, on-screen digitized 2D conventional cephalograms obtained from Dental Imaging Software CS 6.14.3 with CBCT derived 3D lateral cephalograms using CS 3D Dental Imaging v3.5.18.0 software.

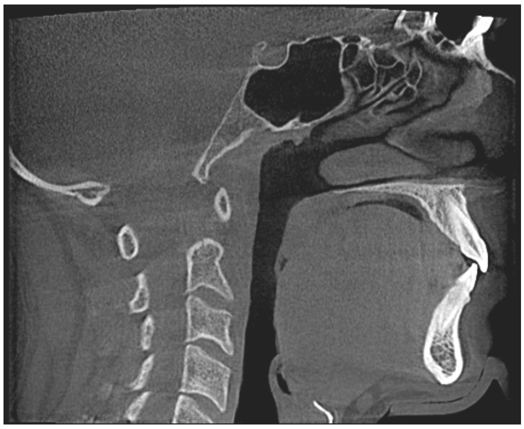
MATERIALS AND METHODS

The present study was carried out in the Department of Orthodontics and Dentofacial Orthopaedics, Government Dental College & Hospital, Ahmedabad. It was approved by the ethical committee. 30 male subjects (18-25 yrs) were selected for the study.

2D Conventional Lateral cephalograms were acquired with CS 9300 all in one imaging system, which offers CBCT, panoramic and Cephalometric imaging in one system. The distance from source to mid-sagittal plane was 152.4 cm (5 feet). A photostimulable phosphor plate was used as the detector and positioned 11.5 cm from the mid-sagittal plane. The subjects were positioned in a cephalostat by fixing between the ear rods, in natural head position with Frankfort horizontal plane parallel to the floor and the mid-sagittal plane perpendicular to the floor. The digital lateral cephalometric images were then printed with Carestream Dry view 5700 Laser Imager on 8” × 10” (20 × 25 cm) high-quality blue 7-mil polyester base T-MAT films (to avoid absorption spreading), at a scale of 1:1 to avoid magnification error.

CBCT images were acquired with the Carestream (CS 9300 V 3.5.18.0) Point-of-Care 3D CT (Carestream Health, Rochester, NY, USA) operated at 90 kvp, 5mA and 0.7 mm nominal focal spot size with exposure time of 11.26 sec, voxel size of 300 × 300 × 300 µm. The subjects were oriented by adjustment of the chin support, in natural head position with Frankfort horizontal plane parallel to the floor and the mid-sagittal plane perpendicular to the floor. A single 360º rotation, 11.26 sec scan, comprising 306 basis projection were made of each skull with a 17.0 cm (diameter) × 13.5 cm (height) field of view and in this field view the cephalometric landmarks can be located and measurements can be derived without full skull CBCT imaging.

A simulated 3D Lateral Cephalogram was produced by adjusting the sagittal reference plane on the axial image to coincide with the midpoint of the sellatursica and increasing the slice thickness from 899 µm to 168.3 mm. Finally CBCT scan of slice thickness of 168.3 mm were obtained and 3D lateral cephalogram generated at this slice thickness was used for the study.



a CBCT scans at slice thickness of 899 µm

b CBCT scans at slice thickness of 17.1 mm

c CBCT scans at slice thickness of 168.3mm

Fig 1

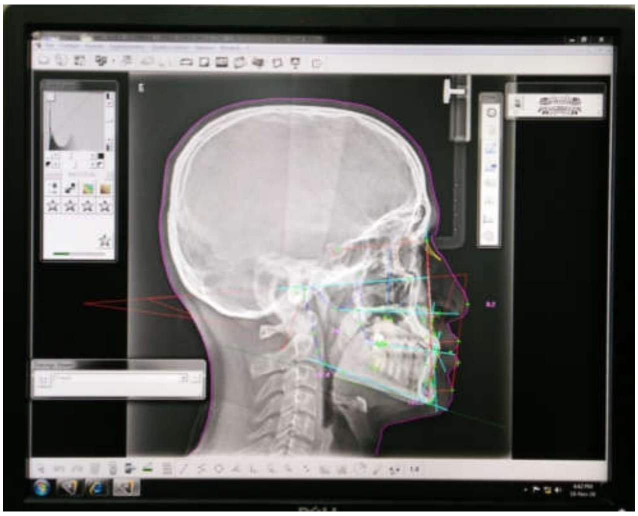


Fig 2 On screen digitized 2D lateral cephalogramusing Dental Imaging Software CS 6.14.3

Fig 3 Digital tracing of CBCT derived 3D lateral cephalograms using CS Imaging v3.5.18.0

Same 30 subjects were evaluated for different tracing techniques in three groups as follows:

Group 1

Angular and linear measurements by Manual tracing method for 2D conventional lateral cephalogram.

Tracing was done manually on 0.36 µm acetate sheet of paper using 0.5 mm lead pencil and measurements were taken.

Group 2

Angular and linear measurements obtained by Dental Imaging Software CS 6.14.3 for on screen digitized 2D conventional lateral cephalogram. Craniofacial structures and cephalometric landmarks were automatically drawn and located by the program so both linear and angular measurements were obtained automatically by Dental Imaging Software CS 6.14.3.

Group 3

Digital tracing by CS 3D Dental Imaging v3.5.18.0 software for CBCT derived 3D lateral cephalograms for angular and linear measurements. 3D CBCT scans obtained were imported in DICOM format (Digital Imaging and Communication in Medicine) in CS v3.5.18.0 software. Landmarks were identified by using a curser driven pointer and linear and angular measurements were obtained.

RESULTS AND DISCUSSION

Two-dimensional (2D) cephalogram have been traditionally considered the modality of choice for the assessment of craniofacial structures for orthodontic cephalometric analysis. However, the superimposition of structures of the left and right side of the skull, the unequal enlargement ratios of the left and right side, and the possible distortion of the mid-facial structures are well-recognized shortcomings of this imaging technique [12-13]. This led to the development of alternative cephalometric analysis approaches. The most recent method is three-dimensional (3D) cephalometry in which the linear and angular measurements are made directly on 3D surface and volume-rendered images obtained from computed tomography (CT) scans[2,14]. The accuracy of these 3D-rendered images has been previously evaluated and the findings showed that direct 3D measurements are highly accurate with no significant discrepancy from physical measurements[15-16]. However, the relatively high radiation dose, costs, and limited availability associated with CT scans impede its adoption to routine clinical orthodontic diagnosis and treatment planning[17].

Table 1

Sr no		Angular Measurements
1.	SNB	Angle between Sella-Nasion plane and a line joining Nasion to Point B.
2.	SND	Angle between Sella-Nasion plane and a line joining Nasion to Point D.
3.	GoGn- SN	Angle formed between SN plane and Mandibular plane
4.	Occl to SN	Angle formed between SN plane and Occlusal plane
5.	FMPA	Angle formed between FH plane and Mandibular plane
6.	IMPA	Angle formed by mandibular plane with long axis ofmandibular central incisor.
7.	Saddle Angle	Angle formed by joining three points (N-S-Ar)
8.	Articular angle	Angle formed by joining three points (S-Ar-Go)
9.	Gonial Angle	Angle formed by joining three points (Ar-Go-Gn)
10.	Basal Plane Angle	Angle formed by the Palatal plane and the Mandibular plane
11.	Occl. to Mand. plane	Angle formed between Mandibular plane and Occlusal plane.
12.	Occl. to FH	Angle formed between FH plane and Occlusal plane.
		Linear Measurements
13.	Co-Gn	Linear distance between Condylion and Gnathion.
14.	Ar-Go	Linea distance from Articulare to Gonion.
15.	Go-Gn	Linear distance between Gonion & Gnathion
16.	Pog to N ⊥	Linear distance between Pogonion & True vertical.
17.	L6 ⊥ MP	Linear distance between tip of mesiobuccal cusp of first molar to mandibular plane.
18.	L1 ⊥ MP	Perpendicular linear distance between incisal edge of lower incisor to mandibular plane.
19.	B-Pog (MP)	Linear distance between point B and a perpendicular to mandibular plane passing through Pogonion

Table 2 Descriptives Values of various parameters in different groups

Parameter	N	2D - Manual Tracing		2D - Software Tracing		3D - Software Tracing	
		Mean	Std. Deviation	Mean	Std. Deviation	Mean	Std. Deviation
Angular Parameters							
SNB	30	83.0	2.5	82.9	2.2	82.5	1.9
SND	30	80.7	2.7	80.6	2.2	80.2	2.2
GoGN-SN	30	22.0	4.9	22.1	4.3	24.8	4.5
Occ-SN	30	13.1	4.0	13.5	4.1	14.5	4.0
Occ-FH	30	9.0	3.9	9.9	3.1	9.0	4.1
FMA	30	19.7	4.7	19.5	4.9	22.7	5.1
N-S-Ar	30	122.3	2.5	121.2	2.6	122.8	3.1
S-Ar-Go	30	141.5	3.9	141.3	4.6	138.0	5.4
Ar-Go-Gn	30	117.6	4.3	119.5	5.1	119.2	5.4
NF-MP	30	19.0	4.5	19.1	4.6	19.2	5.2
Occ-MP	30	11.7	3.7	11.3	3.3	12.3	3.8
IMPA	30	95.5	7.1	97.1	6.8	100.8	7.0
Linear Parameters							
Pog- N⊥	30	4.2	3.30	4.51	2.79	4.2	2.59
Go – Gn	30	75.3	3.46	73.2	3.20	73.1	3.50
Ar-Go	30	52.1	7.14	51.4	5.87	48.7	5.94
Man Molar- MP	30	31.3	1.82	31.3	1.54	31.3	2.49
Man Inc – MP	30	38.2	3.01	38.2	1.88	37.8	2.47
B-Pog (MP)	30	6.2	2.48	6.6	2.27	7.2	2.54
Co-Gn	30	111.2	4.49	110.8	4.28	106.3	4.55

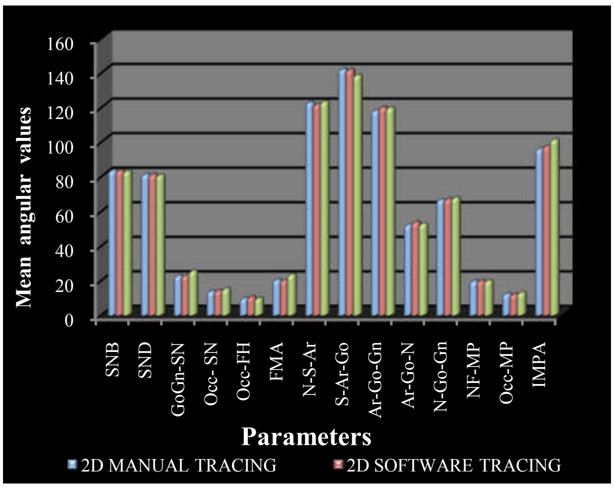
The present study is carried out to determine whether CBCT synthesized 3D cephalograms provide the same accuracy and reliability for measurement as conventional 2D cephalograms when applied to patients. The specific aim is to test the null hypotheses that cephalometric measurements are same either traced manually or computer assisted software for conventional 2D cephalometric radiographs with digitally traced CBCT derived 3D cephalogram

Measurements obtained from 2D conventional lateral cephalograms either traced manually or using onscreen digitization method does not show any significant difference. Of the total 19 mandibular parameters (12 angular and 7 linear) assessed, significant difference was found between 2D conventional lateral cephalograms and Digital tracing for CBCT derived 3D lateral cephalograms for four angular (GoG-SN, FMA, S-Ar-Go, IMPA) & one linear parameter (Co-Gn).

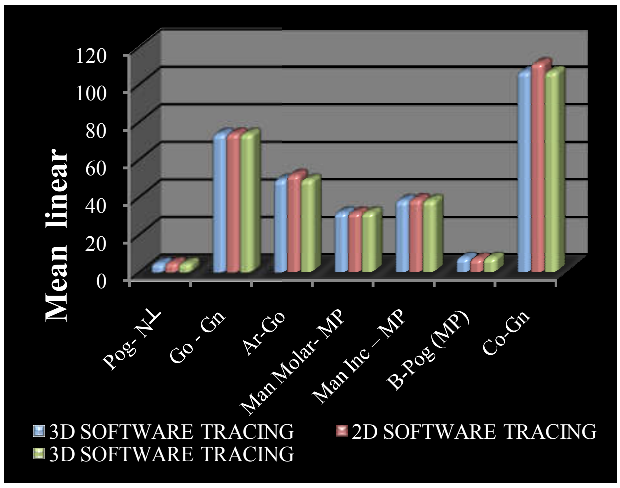
The results of analysis are presented in Table 2, 3 & 4.
Table 3 shows one way ANOVA test to compare measurements between all the three groups and whether difference exist between them. As per results of ANOVA, significant difference is found in the four parameters viz. GoGn-Sn, FMA, S-Ar-Go and IMPA. To compare the difference of each group with the other; a post-hoc LSD test is performed as seen in Table 4;

GoGn-SN angle is statistically significant within the groups [$F(2,87) = 3.639$, $p \leq 0.030$*] which is in accordance with the findings of Olivier J. C. Van Vlijmen *et al.* (2010)[18] and Mauricio Barbosa Guerra da Silva *et al*. (2013)[19]. However this contradicts the findings of U Oz. *et al.* (2011)[20], N Farhadian *et al* (2012)[21], and SecilAksoy *et al*. (2016)[22]. The results of a post-hoc LSD test indicates that the mean score for Group I [M = 22˚ ± 4.9˚] is significantly different than that for Group III [M = 24.8 ± 4.5 ˚] *(p ≤ 0.021)* and also Group II (M = 22.1˚ ± 4.3˚) is significantly different than that for Group III [M = 24.8 ± 4.5˚]*(p ≤ 0.023)*. However, no significant difference is observed between Group I and Group II *(p ≤ 0.966)*.

Olivier J. C. Van Vlijmen *et al.*[18]stated that the probable explanation could be that in the 3D models the angles between two planes are calculated, compared with angles between two



Graph 1 Comparision of Mean Values of All Angular Parameters



Graph 2 Comparision of Mean Values of All Linear Parameters

lines in conventional cephalometry. Mauricio Barbosa Guerra da Silva *et al*.[19]observed statistical significant difference & stated that Gonion point was located in curved surface, which can make the identification more difficult. Also the difference between mandibular contours of Digital Cephalometric & CBCT images were noticed which probably contributed to the difference.

FMA angle statistically significant within the groups [F(2,87) = 4.001, p ≤ 0.022*] which is in accordance with the findings of V Kumar *et al*. (2008)[9].

However this contradicts the findings of N Farhadian *et al* (2012)[21], and Mauricio Barbosa Guerra da Silva *et al*. (2013)[19].The results of a post-hoc LSD test indicates that the mean score for Group I(M = 19.7 ± 4.7) is significantly different than that for Group III [M = 22.7˚ ± 5.1˚]*(p ≤ 0.021)* and also Group II (M = 19.5˚ ± 4.9˚) is significantly different than that for Group III [M = 22.7˚ ± 5.1˚]*(p ≤ 0.013)*. However, no significant difference is observed between Group I and Group II *(p ≤ 0.862)*.

Table 3 Intergroup comparison of various angular & linear parameters

		Sum of Squares	df	Mean Square	F	Sig.
Angular Parameters						
SNB	Between Groups	4.766	2	2.383	0.487	0.616
	Within Groups	425.955	87	4.896		
	Total	430.721	89			
SND	Between Groups	4.826	2	2.413	0.429	0.652
	Within Groups	488.790	87	5.618		
	Total	493.616	89			
GoGN-SN	Between Groups	150.738	2	75.369	3.639	0.030*
	Within Groups	1801.698	87	20.709		
	Total	1952.436	89			
Occ-SN	Between Groups	27.488	2	13.744	0.840	0.435
	Within Groups	1423.521	87	16.362		
	Total	1451.009	89			
Occ-FH	Between Groups	17.678	2	8.839	0.641	0.529
	Within Groups	1200.591	87	13.800		
	Total	1218.269	89			
FMA	Between Groups	190.454	2	95.227	4.001	0.022*
	Within Groups	2070.771	87	23.802		
	Total	2261.225	89			
N-S-Ar	Between Groups	42.950	2	21.475	2.818	0.065
	Within Groups	663.015	87	7.621		
	Total	705.965	89			
S-Ar-Go	Between Groups	233.440	2	116.720	5.292	0.007**
	Within Groups	1896.787	86	22.056		
	Total	2130.227	88			
N-Go-Gn	Between Groups	20.762	2	10.381	0.705	0.497
	Within Groups	1281.339	87	14.728		
	Total	1302.101	89			
NF-MP	Between Groups	.650	2	0.325	0.014	0.986
	Within Groups	1993.815	87	22.917		
	Total	1994.465	89			
Occ-MP	Between Groups	13.154	2	6.577	0.510	0.602
	Within Groups	1122.435	87	12.902		
	Total	1135.589	89			
IMPA	Between Groups	442.158	2	221.079	4.568	0.013*
	Within Groups	4210.323	87	48.395		
	Total	4652.481	89			
Linear parameters						
Pog- N⊥	Between Groups	1.754	2	0.877	0.103	0.902
	Within Groups	738.450	87	8.488		
	Total	740.204	89			
Go-Gn	Between Groups	72.611	2	36.306	3.157	0.058
	Within Groups	966.035	84	11.500		
	Total	1038.646	86			
Ar-Go	Between Groups	184.544	2	92.272	2.291	0.107
	Within Groups	3503.436	87	40.269		
	Total	3687.980	89			
Man Molar-MP	Between Groups	.114	2	0.057	0.014	0.986
	Within Groups	346.635	87	3.984		
	Total	346.749	89			
Man Inc – MP	Between Groups	4.082	2	2.041	0.326	0.722
	Within Groups	543.927	87	6.252		
	Total	548.009	89			
B-Pog (MP)	Between Groups	15.008	2	7.504	1.265	0.287
	Within Groups	516.228	87	5.934		
	Total	531.236	89			
Co-Gn	Between Groups	440.426	2	220.213	11.139	0.000**
	Within Groups	1719.939	87	19.769		
	Total	2160.365	89			

V Kumar *et al.*[9]stated that the landmarks like Porion, and Gonion, which are used to define the Frankfort horizontal plane and the mandibular plane, have greater margins of error. Superimposition of the bilateral middle ear and other temporal fossa structures makes it difficult to identify the anatomic Porion and thus influences the measurement of FMA angle. While viewing anatomy in three dimensions, it is evident that precise landmarks often do not exist. The sharp edges seen in 2D projections are replaced by surfaces and curves in the 3D rendering images thus landmarks like Gonion and Porion are located on curved surfaces and so are difficult to identify accurately.

Table 4 Post HOC LSD test for intergroup comparisons in significant Angular & Linear parameters

Parameter	Group (I)	Group (J)	Mean Difference (I-J)	Sig.
Angular Parameters				
GoGN-SN	Group I	Group II	-0.0500	0.966
		Group III	-2.7700*	0.021
	Group II	Group I	0.0500	0.966
		Group III	-2.7200*	0.023
	Group III	Group I	2.7700*	0.021
		Group II	2.7200*	0.023
FMA	Group I	Group II	0.220	0.862
		Group III	-2.9700*	0.021
	Group II	Group I	-0.2200	0.862
		Group III	-3.1900*	0.013
	Group III	Group I	2.9700*	0.021
		Group II	3.1900*	0.013
S-Ar-Go	Group I	Group II	0.245	0.842
		Group III	3.540*	0.004
	Group II	Group I	-0.245	0.842
		Group III	3.295*	0.008
	Group III	Group I	-3.540*	0.004
		Group II	-3.295*	0.008
IMPA	Group I	Group II	-1.6300	0.367
		Group III	-5.3000*	0.004
	Group II	Group I	1.6300	0.367
		Group III	-3.6700*	0.044
	Group III	Group I	5.3000*	0.004
		Group II	3.6700*	0.044
Linear Parameters				
Co-Gn	Group I	Group II	0.3100	0.788
		Group III	4.8400*	0.000
	Group II	Group I	-0.3100	0.788
		Group III	4.5300*	0.000
	Group III	Group I	-4.8400*	0.000
		Group II	-4.5300*	0.000

Articular angle is statistically significant within the groups ($p < 0.05$) [$F(2,87) = 5.292$, $p \leq 0.007$*] which is in accordance with the findings of N Farhadian *et al* (2012)[21]. The results of a post-hoc LSD test indicates that the mean score for Group I ($M = 141.5^{\circ} \pm 3.9^{\circ}$) is significantly different than that for Group III [$M = 138.0^{\circ} \pm 5.4^{\circ}$]*($p \leq 0.004$*)* and also Group II ($M = 141.3^{\circ} \pm 4.6^{\circ}$) is significantly different than that for Group III [$M = 138.0^{\circ} \pm 5.4^{\circ}$]*($p \leq 0.008$*)*. However, no significant difference is observed between Group I and Group II *($p \leq 0.842$)*.

N Farhadian *et al.*[21] stated that the probable reason might be 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. In Articular Angle, Point Ar (Junction of the posterior ramus plane and the superstructure of the temporal bone) and Gonion are involved. Both landmarks are bilateral landmarks and the technical positioning errors in conventional lateral cephalograms of patients that might have caused difference in these measurements.

Incisor Mandibular Plane Angle (IMPA) is statistically significant within the groups ($p < 0.05$) [$F(2,87) = 4.568$, $p \leq 0.013$*] which is in accordance with the findings of OlivierJ. C. Van Vlijmen *et al.* (2010)[18] and Mauricio Barbosa Guerra da Silva *et al.* (2013)[19]. However this contradicts the findings of R Nalcaci (2010)[5], OlivierJ. C. Van Vlijmen *et al.* (2009)[23], N Farhadian *et al* (2012)[21] and Chang Seo Park *et al.* (2012)[23].The results of a post-hoc LSD test indicates that the mean score forGroup I($M = 95.5^{\circ} \pm 7.1^{\circ}$) is significantly different than that for Group III [$M = 100.8^{\circ} \pm 7^{\circ}$]*($p \leq 0.004$*)* and Group II ($M = 97.1 \pm 6.8$) is significantly different than that for Group III [$M = 100.8^{\circ} \pm 7^{\circ}$]*($p \leq 0.044$*)*. However, no significant difference is observed between Group I and Group II *($p \leq 0.367$)*.

Although Olivier J. C. Van Vlijmen *et al*[18]. Found significant difference, however difference were less than the standard error and hence clinically acceptable. They stated that an explanation for this could be that in the 3D models the angle between two planes are calculated, compared with angle between two lines in conventional cephalometry. Therefore there is a chance that the planes have a different orientation compared with the corresponding line and therefore have a different angle with other planes compared with the use of the lines. Mauricio Barbosa Guerra da Silva *et al.*[19]observed statistical significant difference & stated that Gonion point was located in curved surfaces, which can make the identification more difficult. Also the difference between mandibular contours of Digital Cephalometric & CBCT images were noticed which probably contributed to the difference between the two measurements.

Effective Mandibular length (Co-Gn) is statistically significant within the groups ($p < 0.05$) [$F(2,87) = 11.139$, $p \leq 0.000$**] which is in accordance with the findings of V Kumar *et al.* (2007)[25], HuseyinOlmez *et al.* (2011)[26], U Oz *et al* (2011)[20] and SecilAksoy *et al.* (2016)[22]. However this contradicts the findings of Danielle R Periago *et al.* (2008)[27] and Bruno FrazoGribel *et al.* (2011)[28]. The results of a post-hoc LSD test shows that the mean score forGroup I ($M = 111.2$ mm ± 4.49 mm) is significantly different than that for Group III [$M = 106.36$ mm ± 4.55 mm]*($p \leq 0.00$*)* and also Group II ($M = 97.1$mm ± 6.8 mm) is significantly different than that for Group III [$M = 100.8$ mm ± 7 mm] *($p \leq 0.00$*)*. However, no significant difference is observed between measurements of Group I and Group II *($p \leq 0.788$)*.

V Kumar *et al.*[25]foundlinear mid-sagittal measurements were significantly greater than skull measurements for perspective CBCT because of magnification and distortion, due to inability of Dolphin 3D software to simulate conventional cephalogram which exhibit a mid-sagittal magnification greater than 1:1, unlike Dolphin 3D software which simulate perspective distortion of bilateral structures only maintaining 100% magnification of mid-sagittal plane. HuseyinOlmez *et al.*[26] stated that structures farthest from the film were magnified more than those that were closer to the film. A point which is placed outside the mid-sagittal plane is difficult to locate accurately on 2D cephalogram which results in shortening due to projection of these oblique distances. CT scans provides more precise evaluation of linear measurements. U Oz *et al.*[20]stated difficulties in identification and measurements of landamrks located on the curved surface (such as Go and Co) from CBCT generated cephalogram are still prone to error. Secil Aksoy *et al.*[22] found that the 2D and 3D generated cephalograms from various rendering software were similar, however measurements on curved surfaces are not easily reproducible for 3D software.

CONCLUSION

Of the 19 parameters compared following conclusion can be drawn;

- No significant difference was found between Manual tracing for 2D conventional lateral cephalograms and on screen digitized 2D conventional lateral cephalogram for both angular & linear parameters.
- The digital tracing for CBCT derived 3D lateral cephalograms and measurements from 2D conventional lateral cephalograms via both manual tracing method & on screen digitized 2D lateral cephalogram, yield similar results for majority of the angular & linear parameters, however some discrepancy still exist which might relate to distortion, difficulty in identification of landmarks especially on the curved surfaces and derived landmarks (Gonion, Gnathion, Porion & Condylion).
- The CBCT derived 3D lateral cephalograms provides a true representation of reality and less overlapping of the anatomical structures. The Digital tracing for CBCT derived 3D lateral cephalograms provides overall much more precise cephalometric analysis, lesser risk of operator dependent errors from occurring.
- Synthesized cephalometric images from CBCT may be used to bridge the transition from 2D to 3D image analysis, after correction of the distortion error using any derived mathematical algorithm, so that 3D normal values for 3D quantitative assessment and diagnosis can be derived from previously known 2D norms.

Limitation & Scope for further study

In this study only normal subjects were taken and the research was limited in a particular age and sex group. The future research is needed for multiple observations and also to check for inter-observer and intra observer reliability.

Acknowledgment

The authors extend their sincere thanks to Dr.Nimesh Patel, Dr.Vikalp Patel and Scanmax CBCT Centre for their support for the study.

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How to cite this article:

Ashish Pandey *et al*.2017, Accuracy & Reliabilty of Mandibular Measurements on Lateral Cephalograms & Cbct Scans. *Int J Recent Sci Res.* 8(8), pp. 19212-19219. DOI: http://dx.doi.org/10.24327/ijrsr.2017.0808.0649

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