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Analysis of Pharyngeal Airway Parameters in Vertical Growth Pattern: CBCT vs Lateral Cephalometric Study

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Abstract

Background & objectives: As the basic biological relationship of form and function, changes in the normal pattern of nasopharyngeal space can profoundly affect the development of craniofacial growth. There is a close association between the size of airway spaces and facial morphology. The aim of this study was to assess the reliability of pharyngeal airway parameters between lateral 2D cephalogram and CBCT scan in vertical growth pattern.

Material and methods: 12 linear measurements for pharyngeal airway were analysed in 30 adult subjects (18-25 years) with Autocad digital software CS v 7.0.23.0.d2. for lateral cephalogram (group A) and CS v 3.8.6.0 for CBCT scan- Sagittal cross-section (group B).

Results: Inter modality comparison depicts statistically significant difference (p< 0.005) for Ba-ad1 & Ba-ad2 with more value for lateral cephalogram.

Conclusions: Non-significant difference is found for SPAS, MAS & IAS, Mcnamara airway analysis (UPW,

LPW), VAL, Ptm-ad1, Ptm-ad2, Ba-PNS, PNS- Ppw1 between 2D cephalogram and 3D CBCT scan. However, significant difference for Ba-ad1 & Ba-ad2 with more value in 2D cephalometric analysis.

Keywords: Lateral cephalogram, CBCT

Introduction

Respiratory function is highly relevant to orthodontic diagnosis and treatment planning. Thus, the knowledge of the pharyngeal airway dimensions amongst the various sagittal and vertical facial types is very important and can help an orthodontist in various ways. The reliability of the cephalometric analysis has been questioned previously because two-dimensional representation of a three-dimensional object -restricts it from actual representation, especially of airway area in various growth patterns.

Cone-beam computed tomography (CBCT) provides a superior imaging modality in dentomaxillofacial diagnosis, by offering improved resolution for visualization and lower radiation dose compared with medical CT and can be used in a wide range of patients. CBCT allows easy differentiation between the hard and soft tissues as it has different gray level intensities. It allows the segmentation and visualization of hollow structures such as the airway in 3D. Thus, with the 3D imaging, we are moving from lengths and angles toward volume and surface areas. The generated image by CBCT is isotropic, linear and angular measurements are reliable and anatomically accurate.

Therefore, present study is carried out to determine the accuracy and reliability of pharyngeal airway parameters in vertical growth pattern between lateral 2D cephalogram and 3D CBCT scan by inter observer and intra observer examination.

Material And Methods

For present cross-sectional study, 30 adult subjects (18 – 25 years) with vertical growth pattern which was defined by Jarabak's ratio (less than 62%) and GoGn -SN angle (greater than 34) were selected. It was approved by the ethical committee.

Subject with TMJ disorder, muscle dysfunction, habit of bruxism & nasorespiratory dysfunction were excluded for the study.

Lateral 2D cephalogram and 3D CBCT scan was acquired with CS 9300 all in one imaging system (Figure 1).

Figure 1: Carestream (CS 9300) all in one imaging set-up

The subjects for lateral 2D cephalogram were positioned in a cephalostat in natural head position with Frankfort horizontal plane parallel to the floor and the mid-sagittal plane perpendicular to the floor.

For same subjects, CBCT images were acquired with the Carestream (CS 9300) 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. A single 360º rotation, 11.26 sec scan, comprising 306 basis projections 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). 3D CBCT scan can be produced by adjusting the sagittal reference plane on the axial image to coincide with the midpoint of the Sella tursica, and slice thickness can also be increased from 899 µm to 168.3 mm. But in basic slice thickness of 899 µm identification of some hard tissue landmarks were difficult. Furthermore, in the slice thickness of 168.3 mm some soft tissue landmarks were difficult to identify. So, Finally CBCT scan of 33.9 mm slice thickness were obtained for pharyngeal airway analysis **(Figure 2).**

Figure 2: CBCT scan at slice thickness of 33.9 mm

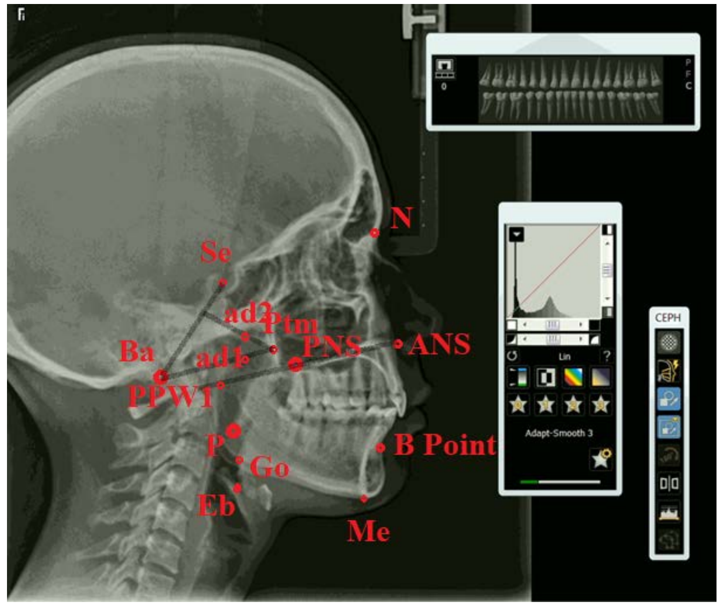
Same 30 subjects were evaluated for different techniques in 2 groups as follows:

Group A: For on screen digitized lateral 2D cephalogram, craniofacial structures and cephalometric landmarks were drawn and located by the program, so linear measurements for airway analysis were obtained automatically by Dental Imaging Software CS 7.0.23.0.d2.

Group B: 3D CBCT scan (sagittal cross-sectional view) obtained was imported in DICOM format (Digital Imaging and Communication in Medicine) in CS v 3.8.6.0 software. Landmarks were identified by using a curser driven pointer and linear measurements of airway analysis were obtained.

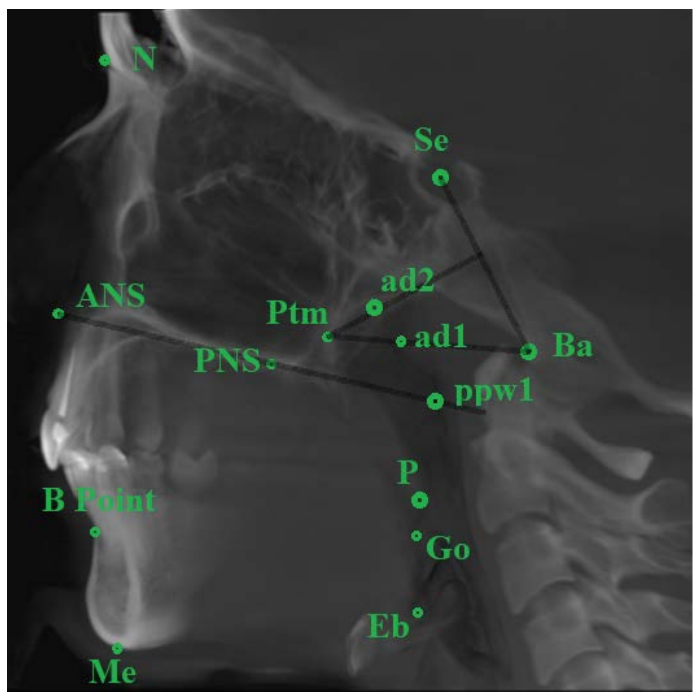
14 Cephalometric Landmarks used for cephalogram and 3D CBCT scan were showed in Figure 3 & 4.

Figure 3: Landmark identification on 2D lateral cephalogram



(1-Nasion, 2-ANS, 3-B-Point, 4-Menton, 5-ad2, 6-Ba, 7-ad1, 8-Ptm, 9-PNS, 10-P, 11- Go, 12-Eb, 13-sella,14-PPW1)

Figure 4: Landmark identification on 3D CBCT scan



(1-Nasion, 2-ANS, 3-B-Point, 4-Menton, 5-ad2, 6-Ba, 7-ad1, 8-Ptm, 9-PNS, 10-P, 11- Go, 12-Eb, 13-sella,14-

PPW1) Following cephalometric Landmarks were used for lateral 2D cephalogram and 3D CBCT scan.

1	Nasion	The most anterior point on the frontonasal suture in the midsagittal plane.
2	ANS	The anterior tip of the sharp bony process of the maxilla at the lower margin of the anterior nasal opening.
3	point B	The most posterior midline points in the concavity of the mandible between the most superior point on the alveolar bone overlying the mandibular incisors and pog.
4	Menton	The lowest point on the symphyseal shadow of the mandible.
5	ad2	Point of intersection of posterior pharyngeal wall and line from Ptm as normal perpendicular to S-Ba.
6	Ba	The lowest point on the anterior rim of the foramen magnum.
7	ad1	Point of intersection of posterior pharyngeal wall and line Ptm to Ba.
8	Ptm	The lowest point of opening - the contour of pterygomaxillary fissure formed anteriorly by the retromolar tuberosity of the maxilla and posteriorly by the anterior curve of the pterygoid process of the sphenoid bone.
9	PNS	The posterior spine of the palatine bone constituting the hard palate.
10	P	Tip of soft palate.
11	Go	A point on the curvature of the angle of mandible located by bisecting the angle formed by lines tangent to the posterior ramus and the inferior border of the mandible.
12	Eb	Base of epiglottis.
13	Sella	The geometric center of the pituitary fossa
14	ppw1	Posterior pharyngeal wall intersection with ANS-PNS line.

12 cephalometric linear measurements of pharyngeal airway analysis were taken for lateral 2D cephalogram and 3D CBCT scan (Figure 5 & 6).

Figure 5: Linear measurement of pharyngeal airway parameters on lateral 2D cephalogram.

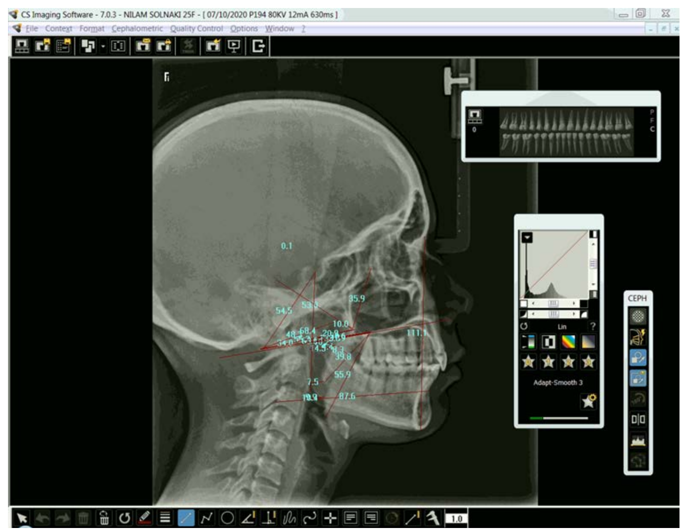
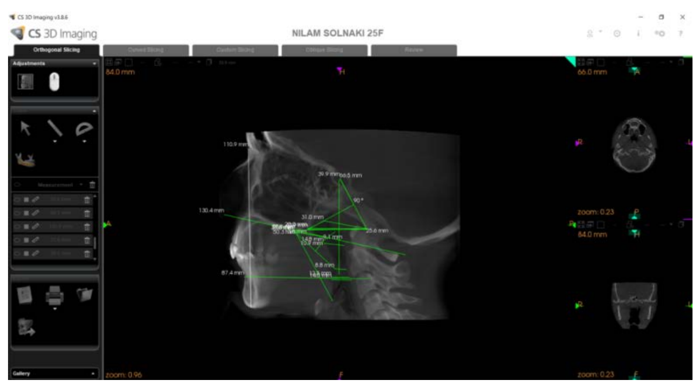


Figure 6: Linear measurement of pharyngeal airway parameters on 3D CBCT scan



1. **SPAS**: superior posterior airway space (width of airway behind soft palate along parallel line to Go-B line).

2. **MAS**: middle airway space (width of airway along parallel line to Go-B line through P).
3. **IAS:** inferior airway space (width of airway space along Go-B line).
4. **VAL**: vertical airway length (distance between PNS and Eb).
5. **UPW: (Upper pharyngeal width** is measured from a point on the posterior outline of the soft palate to the closest point on the pharyngeal wall.)
6. **LPW: (Lower pharyngeal width** measured from the point of intersection of the posterior border of the tongue and the inferior border of the mandible to the closest point on the posterior pharyngeal wall.)
7. **Ptm – ad 1: (Ptm: Pterygomaxillary fissure:** most inferior point on average of right and left outlines of pterygomaxillary fissure, **ad l** - Point of intersection of posterior pharyngeal wall and line ptm to Ba.)
8. **Ptm – ad 2: (Ptm: Pterygomaxillary fissure:** most inferior point on average of right and left outlines of pterygomaxillary fissure, **ad 2:** Point of intersection of posterior pharyngeal wall and line from ptm as normal perpendicular to S-Ba.)
9. **Ba – ad 1:** (**Ba: Basion** - lower most point on anterior margin of foramen magnum, **ad l** - Point of intersection of posterior pharyngeal wall and line ptm to Ba.)
10. **Ba – ad 2: (Ba: Basion** - lower most point on anterior margin of foramen magnum, **ad 2:** Point of intersection of posterior pharyngeal wall and line from ptm as normal perpendicular to S-Ba.)
11. **Ba - PNS**: (**Ba**: **Basion** - lower most point on anterior margin of foramen magnum, **PNS: Posterior nasal spine** - tip of posterior spine of palatine bone in hard palate.)
12. **PNS – ppw 1: (PNS: Posterior nasal spine** - tip of posterior spine of palatine bone in hard palate, **ppw l:** Posterior pharyngeal wall intersection with ANS-PNS line.

Identification of 14 landmarks and 12 linear measurements of pharyngeal airway analysis were recorded for cephalogram and 3D CBCT scan and thus data obtained was subjected to statistical analysis selected.

Result and Discussions

Statistical analysis using SPSS version 23. Descriptive & independent T test was done and $P < 0.05$ was considered as level of confidence. Upper airway and its relationship with craniofacial morphology is extremely important in orthodontic diagnosis and treatment planning. Few studies have shown that there is some definite correlation between the growth pattern of the maxillo-mandibular complex and Naso respiratory function.

Table 1 and Table 2 shows the descriptive statistics of lateral 2D cephalogram and 3D CBCT scan respectively. **Table 3** shows the inter modality comparison between 2D lateral cephalogram and 3D CBCT scan, all linear measurements are non-significant ($p>0.05$) except Ba-ad1 and Ba-ad2 which are statistically significant ($p<0.05$*) with more mean and standard deviation for 2D cephalogram analysis than 3D CBCT scan. This may be due to error in identification of the curved surface landmarks - Point B, Gonion and posterior pharyngeal wall for2D cephalogram.

TABLE 1: Descriptive statistics of lateral 2D cephalogram

Parameter	N	Minimum	Maximum	Mean	Std. Deviation
SPAS	30	9.1	15.8	12.687	1.8636
MAS	30	6.0	10.2	8.413	1.2202
IAS	30	7.1	12.7	10.343	1.5240
VAL	30	51.7	69.0	60.713	4.2320
UPW	30	8.0	15.8	11.323	1.6269
LPW	30	7.3	13.3	10.297	1.5899
Ptm-ad1	30	14.3	26.9	20.290	3.4438
Ptm-ad2	30	8.6	24.2	14.703	3.4917
Ba-ad1	30	17.8	35.8	27.280	5.1899
Ba-ad2	30	26.7	44.5	34.767	4.1189
Ba- PNS	30	41.9	63.4	52.213	5.4076
PNS-Ppw1	30	21.3	36.7	28.777	4.2975

TABLE 2: Descriptive statistics of lateral 3D CBCT scan

Parameter	N	Minimum	Maximum	Mean	Std. Deviation
SPAS	30	9.7	15.5	12.71	1.52
MAS	30	7.2	10.2	8.56	0.90
IAS	30	8.0	12.4	10.61	1.17
VAL	30	51.9	67.8	60.68	4.33
UPW	30	9.2	14.9	11.05	1.51
LPW	30	7.7	12.9	10.13	1.47
Ptm-ad1	30	13.8	27.7	19.31	3.37
Ptm-ad2	30	8.9	22.6	14.38	3.16
Ba-ad1	30	16.9	35.4	26.48	4.58
Ba-ad2	30	25.3	42.7	34.02	3.79
Ba- PNS	30	42.3	59.7	52.15	5.05
PNS-Ppw1	30	22.2	36.3	29.15	3.69

TABLE 3: INTER MODALITY COMPARISON BETWEEN LATERAL 2D CEPHALOGRAM AND 3D CBCT SCAN

		2D		3D		
Parameter	N	Mean	SD	Mean	SD	P value
SPAS	30	12.69	1.86	12.71	1.52	0.536 NS
MAS	30	8.41	1.22	8.56	0.90	0.146 NS
IAS	30	10.34	1.52	10.61	1.17	0.281 NS
VAL	30	60.71	4.23	60.68	4.33	0.473 NS
UPW	30	11.32	1.63	11.05	1.51	0.296 NS
LPW	30	10.30	1.59	10.13	1.47	0.051 NS
Ptm-ad1	30	20.29	3.44	19.31	3.37	0.588 NS
Ptm-ad2	30	14.70	3.49	14.38	3.16	0.404 NS
Ba-ad1	30	27.28	5.19	26.48	4.58	0.026*
Ba-ad2	30	34.77	4.12	34.02	3.79	0.044*
Ba- PNS	30	52.21	5.41	52.15	5.05	0.082 NS
PNS-Ppw1	30	28.78	4.30	29.15	3.69	0.072 NS

NS – Not significant (p>0.05), *-Significant (p<0.05), **-Highly significant (p<0.001)

Wun hsu et al obtained information on upper airway anterior-posterior distance (PAS- constricted anterior-posterior distance of upper airway, from which a line was traced from the posterior wall of the pharynx - anterior wall of the pharynx) by comparing lateral cephalograms and CBCT under upright and supine postures respectively. He found a negative correlation with no statistically significant difference for PAS by intra-examiner reliability.

MG Lenza et al evaluated the degree of correlation between assessments of the upper airway (from the top of the epiglottis to adenoids) performed by linear measurements (ad2-PNS, ad1-PNS, PNS-P, T2-P3, P-P', Phw2-Tb, E2-E1) in the sagittal and the transversal plane of space and cross-sectional areas and volumes were calculated, a weak correlation (r < 0.8) was found. The sagittal linear measurements were weakly correlated (r < 0.8) with area measurements, except at the level of ad2-PNS where a high correlation (r > 0.9) was found. Between transversal measurements and area measurements, a good correlation (0.8 < r < 0.9) was found for almost all the sites, except for ad2-PNS and E2-E1.

Cameron Aboudara et al compared imaging information about nasopharyngeal airway size between a lateral cephalogram and a 3-dimensional (3D) cone-beam computed tomography (CBCT) scan in adolescent subjects. He found a significant positive relationship between nasopharyngeal airway size on a head film and its true volumetric size from a CBCT scan. But, accurate determination of airway volume for a patient from a head film is difficult because of the greater variability in the 3D airway. Mariana vizzotto et al. evaluated the correlation of linear and area measurements in two-dimensional views from specific airway regions of interest and compared them to corresponding volume in CBCT. He found the highest positive correlations in the nasopharynx and oropharynx sagittal areas and the most constricted area in the oropharynx are the most 2D-correlated measurements to the volume when evaluating upper airway measurements.

Pisha pittayat et al evaluated the accuracy of linear measurements (N–ANS, N–A, N–B, N–Me, ANS–Me, ANS–PNS, Ba–PNS) on three imaging modalities. They found that the intra and inter observer agreement was better for 3D measurements from both cephalometric devices when compared with 2D measurements. These findings demonstrated the linear measurement accuracy and reliability of 3D measurements based on CBCT data when compared to 2D techniques.

Vertical growth pattern without consideration of sagittal discrepancy indicators was taken in the present study. So, further studies with different growth patterns including the sagittal skeletal malocclusion & gender predominance may yield a more conclusive results for reliability of linear and angular pharyngeal airway parameters.

Conclusion

Non-significant difference is observed for SPAS, MAS, IAS, VAL, Ptm-ad1, Ptm-ad2, PNS-ppw1 between 2D cephalogram and 3D CBCT scan. Significant difference is observed in Ba-ad1 & Ba-ad2 with more value in 2D cephalometric analysis.

This may be due to distortion, magnification error, different technical specifications, slice thickness, overlapping and superimposition in anatomical landmarks for Ba, PNS, Ptm, soft palate, posterior surface of tongue, inferior border of the mandible and posterior pharyngeal wall.

The limitation of 2D cephalogram which results in distorted images need to be corrected and required by any derived mathematical algorithm. And so, 3D values for 3D quantitative assessment & diagnosis can be derived from known 2D norms without exposing the patient to radiation.

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