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# Cone Beam Computed Tomography (CBCT) In The Assessment Of The Airway: A Review

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**Abstract**
Cone Beam Computed Tomography (CBCT) is being used extensively for airway assessment which forms an important part of orthodontic diagnosis and treatment planning. It has emerged as a powerful imaging tool because of its low cost, high spatial resolution, reduced radiation exposure and smaller footprint in compared to multi slice medical CT. This purpose of this article is to collate the most recent developments and research in the field of airway assessment with CBCT and to shed some light on the advantages and disadvantages associated with its use.
**Keywords :** CBCT, airway, obstructive sleep apnoea.

## I. INTRODUCTION

Airway assessment has been an integral part of facial morphological assessment in dentistry. The association between changes in facial morphology, airway volume and respiratory disorders like mouth breathing and obstructive sleep apnoea has been extensively debated in the literature[1-3] and remains controversial and one that clinicians have long sought to elucidate. There are two conflicting schools of thought - one that considers breathing pattern an important etiological factor in causing the long face syndrome (LFS) and the other which believes that LFS expresses an inherited pattern and breathing pattern would act only as an aggravating factor. Currently, it is believed that skeletal morphology is a result of genetically determined growth superimposed by the action of its functional matrix. This has prompted several researchers to study the relationship between orthodontic treatment and changes in airway volume. Traditionally, airway assessment was carried out using lateral cephalometric radiographs which are routinely taken as part of pre-treatment patient records. Although it can provide a wealth of information, it is limited in accuracy since it produces two-dimensional images of a three-dimensional structure[2,3,4].

The relatively recent involvement of orthodontists with obstructive sleep apnea (OSA) in both children and adults has led to an increased interest in the assessment of the upper pharyngeal airway. Obstructive sleep apnea (OSA) is a highly prevalent disease, characterized by upper airway collapse during sleep resulting in recurring arousals and desaturations. The clinical consequences are significant and often serious and include daytime hypersomnolence, cardiovascular disease, neurocognitive dysfunction, respiratory failure, and cor pulmonale[5,6]. As a result, OSA represents an increasing burden on health care resources. The etiology is multifactorial and often involves a significantly constricted upper airway compared to individuals without OSA, amongst other factors that may include rhinitis, deviated septum, polyps, tonsils, adenoids, and tumors. To be able to determine the degree and location of constriction and evaluate the effectiveness of treatment, nasopharyngoscopy, fluoroscopy, rhinomanometry, cephalometry, MRI, and CT have been used[7].

The introduction of Cone Beam Computed Tomography (CBCT) revolutionised dental radiography and diagnosis when it became readily available in the late 1990s. CBCT has made it possible to acquire 3D image volumes of all structures in the maxillofacial complex and aids in the assessment of cross-sectional areas of the coronal, sagittal and axial planes of the airway anatomy. This enables it to overcome the challenges faced by two-dimensional imaging such a lateral cephalograms. Reduced patient exposure to radiation, larger field of vision (FOV) and improved image quality with short scanning time has made it a better choice than CT and a valuable tool in airway assessment.[8] These factors along with the relatively recent and increased awareness in obstructive sleep apnea (OSA) in children and adults has driven the assessment of the upper pharyngeal airway using CBCT to the forefront of academic and clinical interest.

## II. CBCT IN AIRWAY ASSESSMENT

A recent systematic review has noted that despite extensive studies there is a lack of uniformity in patient positioning while acquiring the images, the terminologies & landmarks used to define the extent of the upper airway, and predictably variety of machines and software were used in airway evaluation[7].

### *Protocol for Image Acquisition*

Patient positioning while acquiring an CBCT image can affect the results of volumetric analysis. In previous studies, patients have been positioned in either supine or upright position. The Frankfort horizontal (FH) plane perpendicular to the floor in case of supine position. For the upright position, the FH plane is parallel to the floor with patients maintaining their natural head position and maximum intercuspation[7,9]. The choice of patient positioning is often influenced by the type of CBCT machine in dental office and the upright machines are more commonly used. However, examinations which are done with the patient in the supine position results in movement of soft tissue structures towards the posterior pharyngeal wall which naturally results in a change in the airway dimension[9]. Therefore measurements obtained in a supine position and in a sitting position cannot be compared; with the supine position being the preferred choice in suspected OSA patients. A modification to this technique was suggested by Lohse et al[9] namely to remove the chin positioner so that the patient can hold their head in a natural position.

The head, body and jaw position at the time of scan acquisition have a significant impact on the upper airway dimension as described by Gurani et al., in a systematic review.[10] Other confounding factors include the tongue posture and the respiratory phase which can qualitatively and quantitatively affect the size and shape of the oropharynx. These errors can be controlled by instructing the patient to avoid swallowing and any other movement during the CBCT scan, breathe gently, and maintain the mandible in a reproducible position, either maximum intercuspation or centric relation.[8]

Studies have used field of view (FOV) ranging from 13cm to 30 cm. Larger FOV should be used to cover the entire airway, whereas smaller FOV can be utilized to image only nasopharynx or oropharynx. A tube potential of 120 kVp was used in most studies, and tube current ranged from 1 mA to 15 mA. The scan time varied greatly between studies (9.6–40 s) and the voxel size ranged from 0.25 mm to 0.6 mm. These values will be dependent on the type of CBCT machine utilized. Upon completion of the CBCT examination, some manipulations can be performed using the software provided by the scanner manufacturer. The raw image (raw data) is reconstructed to enable visualization of 3D reconstruction and multiple planar cross-sections. These two-dimensional images of the pharynx can be examined from any direction. The most commonly used are sagittal, coronal and axial. Volumetric assessments are carried out using various tools available within the software used.[1,8,7]

***Airway Assessment***

*Orientation of the CBCT image*: Prior to evaluation of the CBCT images it is essential to orient the coronal, sagittal and axial images according to specific planes to optimize reproducibility. The orientation of the Coronal view is done so that the most inferior point on the infraorbital margin (orbitale) of both sides lies on the same horizontal plane ; for the sagittal plane the Frankfort plane (line joining the most superior point on the external auditory meatus to the infraorbital margin) is horizontal. The axial plane is oriented so that the line through the crista galli and the midpoint on the anterior margin of foramen magnum (basion) is vertical. Several other planes for orientation have been described by Balachandran et. al.,[11] which could be followed.

Various studies have defined the upper airway is through various hard and soft tissue landmarks on a CBCT image. The hard tissue landmarks utilized include - hard palate, posterior nasal spine (PNS), basion (Ba), hyoid bone, retrognathion point (RGn), B point (B), and mental point (Me), Orbitale, Sella turcica, Porion, Nasion ect. The soft tissue references were composed of the tip of the uvula, tip of the epiglottis, base of the epiglottis, and base of the tongue. Frankfurt plane, palatal plane, and occlusal plane were also used by some studies references to upper airway delineation.[7,8,9,12] Gabriele Di Carlo et al[13] have described several planes to divide the airway into Retropalatal, Upper retropalatal, Lower retropalatal, to increase accuracy while comparing the airway pre and post orthognathic surgery. Differences in upper airway assessment exist between adults and children, as anatomically structures vary with growth and development. Anandarajah et al.,[14] in their study have defined the extent of airway for children and have suggested following margins for evaluation of CBCT images:- 1. Superior: the line passing from the palatal plane (anterior nasal spine to posterior nasal spine) extending to the posterior wall of the pharynx ; 2. inferior: line passing from the anterosuperior edge of the fourth cervical vertebra (C4) to menton; 3. Anterior: line passing from the soft palate to menton; 4. posterior: posterior wall of the pharynx; 5.Lateral: respective pharyngeal walls.

Parameters assessed include, volume, linear measurements in axial, coronal and sagittal sections reported as cross-sectional areas in different areas. The role of the respiratory cycle during imaging acquisition were assessed by computer simulations. Additionally, velocity, resistance, pressure, and UA wall stress have also been evaluated. The various machines and different software have proven to reliable in their measurements. Technological developments in machine learning and automated tools now are utilized in assessment of airway. [4]

While selecting landmarks for delineation of airway it should be noted that the position of the soft tissue landmarks will vary due to physiological neuromuscular activity, and thus hard tissue landmarks may be a better choice for the most accurate and reproducible evaluation. Also, in case of measurements to be carried out pre and post-surgical, it is best to utilize bony landmarks that will not be altered after surgery.[13]

## III. RELIABILITY OF AIRWAY ASSESSMENT USING CBCT

A systematic review done by Zimmerman et al[7] showed that there were several methodological limitations in previous studies which assessed the upper airway using CBCT. Image orientation and selection of threshold sensitivity was not done in spite of these steps being very prone to subjectivity.

It was found that the oropharynx is the only region of the upper pharyngeal airway to show excellent intra and inter-examiner reliability. There are several explanations for this – one being that the shape of the oropharynx being like a hollow tube, allows for easy processing for the software. The nasopharynx and the hypopharynx in comparison have much more complicated anatomies.[12,16,17]

The selection of threshold sensitivity value for the airway showed poor inter and intra-examiner reliability. It was also found that the slow scan protocol showed higher reliability than the fast scan protocol, more so for inter-examiner reliability than for intra-examiner reliability. This could be attributed to increased scan time, decreased voxel size and increased tube current which provides greater resolution in the image.[12]

## IV. CBCT AIRWAY ANALYSIS AND CRANIOFACIAL MORPHOLOGY

Several studies have examined the variation of airway parameters with differences in maxillomandibular relationship. Studies have been divided in terms of gender differences associated with airway morphology with Daniel et al., [18] showing significant differences between males and females and El and

Palomo et al.,[17] showing contradictory results. Jayaratne and Zwahlen,[19] in their study, observed a considerably higher value for the oropharyngeal airway volumes among Class III subjects when compared to Class II individuals, which was also noted by Nath et al,[20]. A study by Lopatienė et al. [21]revealed that a decrease of the SNB angle by 1° increased the risk of a 1 mm reduction in the width of the upper pharynx by 17%.

## V. CBCT AIRWAY ANALYSIS AND SLEEP APNEA

Li et al.,[22]have also demonstrated a relationship between the airway area and the likelihood of obstructive sleep apnea (OSA). There is a high probability of severe OSA if the airway area is less than 52 $mm^2$, an intermediate probability if the airway is between 52 to 110 $mm^2$, and a low probability if the airway is greater than 110 mm2. Lowe et al., demonstrated that most constrictions occur in the oropharynx with a mean airway volume of 13.89  5.33 cm3. Barkdul et al.,[23] demonstrated a correlation between the retro-lingual cross-sectional airway and OSA when this area was less than 4% of the cross-sectional area of the cervicomandibular ring. Eow et al.,[24] have found that CBCT airway volume assessment correlated with STOP-Bang scores which are used to assess the risk for OSA and concluded that CBCT could be potentially used to screen patients for OSA. In paediatric population, Hsu et al.,[25] found that CBCT measurements demonstrated that children with moderate-to-severe OSA have a significantly smaller airway volume and minimal airway area in nasopharynx and oropharynx than those with primary snoring and concluded that 3D CBCT airway analysis can be a useful tool to evaluate upper airways in children with OSA. However, a recent systematic review has shown that further studies are required to assess the usefulness of CBCT in assessing OSA patients after they undergo surgical or dental appliance.

## VI. CONCLUSION:

The lower radiation dose compared to medical CT and the ability to assess the upper pharyngeal airway in three dimensions makes CBCT an attractive potential tool for the assessment of the airway. CBCT has proven to be a reliable tool in oropharyngeal airway assessment. However, further studies are required to standardize the protocol used for airway assessment in CBCT images and its use in long term follow up of patients.

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