

Cone-Beam Computed Tomography Evaluation of the Oropharyngeal Airway in Preadolescent Patients with Nonsyndromic Cleft Lip and Palate: A Mini- Review

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Abstract: Cleft lip and palate (CLP) is one of the most common craniofacial anomalies and may cause significant alterations in airway morphology and function. The advent of cone-beam computed tomography (CBCT) has provided a reliable, low-dose, three-dimensional tool to assess upper airway dimensions in growing patients. This mini-review summarizes current findings on oropharyngeal airway characteristics in preadolescent patients with nonsyndromic unilateral and bilateral CLP. CBCT-based studies generally demonstrate reduced oropharyngeal volumes and altered airway morphology compared with non-cleft controls. Bilateral cases often show greater constriction than unilateral ones, although methodological heterogeneity limits definitive conclusions. Standardized imaging protocols, artificial-intelligence segmentation, and integration with functional tests such as polysomnography are needed to improve understanding and clinical translation.

Keywords: cone-beam computed tomography; airway; oropharynx; cleft lip and palate; preadolescent; mini-review.

Introduction

Cleft lip and/or palate (CL/P) affects approximately one in 700 live births and is associated with skeletal and soft-tissue deformities that alter the maxillary, nasal, and pharyngeal regions. These structural abnormalities can compromise airway patency and predispose affected children to nasal obstruction or sleep-disordered breathing (SDB). Accurate evaluation of the upper airway is therefore critical in planning surgical and orthodontic treatment. Traditional two-dimensional radiographs are limited in capturing airway morphology. The introduction of cone-beam computed tomography (CBCT) has revolutionized craniofacial imaging, providing three-dimensional visualization of airway structures at relatively low radiation doses. CBCT allows volumetric and cross-sectional measurements of the naso- and oropharyngeal spaces, facilitating comparisons between cleft and non-cleft populations.

CBCT in Airway Assessment

CBCT enables segmentation of the airway into defined regions—typically the nasopharynx, oropharynx, and hypopharynx—and the calculation of total airway volume, minimum cross-sectional area (MCA), and airway length. Compared with medical CT, CBCT offers lower radiation exposure, faster scanning, and high spatial resolution. However, CBCT captures the airway under static, awake conditions. Measurements can be influenced by head posture, tongue position, and respiratory phase, which must be standardized to ensure reproducibility. Despite these limitations, CBCT remains the gold-standard imaging method for anatomical airway assessment in CL/P patients.

Airway Characteristics in Cleft Lip and Palate Patients

General Findings - Recent CBCT studies show that children with repaired CL/P often have smaller naso- and oropharyngeal airway volumes and a reduced minimal cross-sectional area compared with non-cleft controls. These reductions correlate with maxillary hypoplasia, altered tongue posture, and posterior displacement of the soft palate. The degree of airway compromise varies among individuals, likely reflecting differences in surgical techniques, scar tissue, and growth pattern.

Bilateral versus Unilateral CLP - Comparative research indicates that bilateral CLP (BCLP) patients generally present with more severe airway constriction than unilateral CLP (UCLP) patients. This may result from greater maxillary retrusion and narrower pharyngeal skeletal support in bilateral cases. Nevertheless, other studies report no significant differences, suggesting that surgical and developmental variability plays a major role.

Morphological Features

CBCT analyses reveal changes not only in airway size but also in shape and orientation. In many CL/P patients, the minimal airway is located lower in the oropharynx, with a more triangular or flattened cross-section. Such alterations may increase airflow resistance and predispose to breathing difficulties or snoring.

Methodological Considerations

Differences among CBCT studies often arise from inconsistent anatomical boundaries, voxel resolution, and segmentation techniques. Some define the upper airway limit at the posterior nasal spine, while others use the hard-palate plane; lower limits may extend to the hyoid bone or epiglottis. These discrepancies make inter-study comparisons difficult. Automated or AI-assisted segmentation is increasingly used to minimize human bias and improve repeatability. Additionally, growth stage strongly influences airway volume; therefore, preadolescent samples should be analyzed in narrow age brackets or with growth-adjusted models.

Clinical Implications

Airway assessment in CL/P patients is vital for:

1. Surgical planning: Maxillary advancement or distraction osteogenesis can significantly enlarge pharyngeal airway dimensions. 2. Orthodontic and orthopedic therapy: Interventions such as rapid maxillary expansion or bone-anchored maxillary protraction (BAMP) may improve nasal airflow and airway volume. 3. Sleep health monitoring: Since CL/P patients show higher prevalence of SDB symptoms, periodic airway evaluation is recommended. CBCT may serve as a complementary tool to clinical and polysomnographic assessments.

Future Directions

Emerging technologies such as AI-based segmentation and computational fluid dynamics (CFD) modeling can link CBCT-derived airway geometry to functional airflow dynamics. Integration with polysomnography (PSG) and longitudinal follow-up through growth will clarify how surgical and orthodontic interventions influence airway development. Standardized CBCT protocols and international consensus on airway landmarks are needed to ensure reproducible research outcomes.

In Conclusion, CBCT provides a valuable three-dimensional perspective for analyzing airway morphology in children with nonsyndromic CL/P. Most studies reveal reduced oropharyngeal volumes and altered airway shapes, particularly in bilateral cases. Despite methodological variability, evidence supports the need for routine airway monitoring in comprehensive cleft care. Future research combining standardized CBCT imaging with AI-driven analysis and functional evaluation will enhance our understanding of airway physiology and guide more effective treatment strategies.

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