



Original research

Three-dimensional Evaluation of the Airway and Maxillary Atresia in Skeletal Class II Children

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ABSTRACT

Introduction: Skeletal Class II and maxillary atresia may affect upper airway dimensions, influencing respiration and craniofacial development. Cone-beam computed tomography (CBCT) enables precise three-dimensional assessment. **Objective:** To describe upper airway dimensions and maxillary morphology in pediatric patients with skeletal Class II using CBCT. **Material and Methods:** An observational study was conducted on children aged 7 to 11 years with skeletal



Class II. Maxillary (PIL, PAD, MPAA) and airway (total volume, minimum area, nasopharynx, oropharynx) parameters were analyzed using descriptive and inferential statistics. **Results:** A total of 37 patients (mean age: 8.78 ± 1.38 years) were included. High variability was observed in maxillary and airway dimensions. Maxillary atresia was present in 62% of cases, predominantly in females (73%). No consistent airway reduction pattern was identified. **Conclusion:** This study provides a detailed characterization of upper airway dimensions and maxillary morphology in children with skeletal Class II. The observed variability suggests multiple influencing factors. CBCT enables precise assessment of these dimensions, aiding diagnosis and treatment planning in maxillofacial orthopedics.

Keywords: Maxillary Atresia, Upper Airway, Skeletal Class II, CBCT, Pediatrics.

INTRODUCTION

The stomatognathic system, composed of skeletal, muscular, and dental structures, plays a key role in functions such as chewing, swallowing, breathing, and phonation. Alterations in these functions can cause dysfunctions that impact the entire body, so early diagnosis in pediatric patients is essential to promote proper development, prevent sequelae, and reduce the need for invasive treatments^{1,2}.

Skeletal classes refer to the spatial relationship between the maxilla and mandible in relation to the skull base, which can be affected by a variety of genetic and environmental factors, leading to different types of malocclusions, such as misalignment of the teeth and the way the upper and lower teeth fit together³. Skeletal class II, characterized by mandibular retrusion or maxillary protrusion, is associated with narrower upper airways, increasing the risk of respiratory disorders such as obstructive sleep apnea syndrome (OSAS). This syndrome, which is common in the pediatric population, not only affects sleep quality but also craniofacial development and overall well-being⁴⁻⁶.

Another relevant factor in craniofacial morphology is maxillary atresia, which is defined as a deficiency in the transverse dimension of the maxilla, affecting the correct alignment of the teeth and reducing the available space in the palate, which, in turn, can lead to upper airway obstruction. Maxillary atresia has been extensively studied in adults, but there is little literature about its prevalence and effects in the pediatric population. The combination of a narrow upper airway and maxillary atresia can exacerbate respiratory problems, underscoring the need for more detailed studies in young patients^{7,8}.

In this context, various functional factors such as mouth breathing, chronic nasal obstruction, and persistent oral habits have been associated with the development of maxillary atresia in pediatric patients with skeletal class II. These conditions alter muscle balance and tongue position, promoting transverse narrowing of the maxilla and simultaneously compromising the morphology of the upper airway^{6,9}.

Cone beam computed tomography (CBCT) has transformed craniofacial evaluation by providing three-dimensional images that reduce the need for multiple conventional radiographs and decrease radiation exposure. It also facilitates the simultaneous evaluation of upper airway dimensions and transverse maxillary deficiencies, which helps improve the diagnosis and treatment of these disorders in clinical practice^{10,11}.

Therefore, the main objective of this study is to explore the relationship between skeletal class II, upper airway dimensions, and maxillary atresia in pediatric patients attending the postgraduate pediatric clinic of the Faculty of Stomatology of the Benemérita Universidad Autónoma de Puebla (BUAP), Mexico, using CBCT for a comprehensive evaluation, to optimize the diagnosis and generalized treatment of maxillofacial orthopedics.

MATERIALS AND METHODS

An observational and prospective study was conducted on patients who attended the pediatric postgraduate clinic at the Faculty of Stomatology of the Benemérita Universidad Autónoma de Puebla (BUAP) between September 2023 and July 2024. Patients between the ages of 7 and 11 were selected and included only if their legal guardians gave informed consent. Also, an informed consent was obtained through an age-appropriate explanation. Patients who had received preventive and interceptive orthodontic treatments that could alter the results were excluded. CBCT scans were performed to evaluate airway dimensions and maxillary atresia. The research was conducted in accordance with the ethical principles established by CIOMS/WHO (2002) and the Declaration of Helsinki (WMA, 2009), as well as the guidelines of Article XI of the Mexico's Ley General de Salud. In addition, it was carried out in accordance with the rules stipulated by the Research Committee of the BUAP School of Stomatology, with registration number 2023227.

Skeletal class was determined using the ANB angle from Steiner's cephalometric analysis, with angles greater than 4° classified as class II¹². To evaluate maxillary atresia, several key dimensions were measured, including palatal interalveolar length (PIL), palatal arch depth (PAD), and maxillo-palatal arch angle (MPAA). The interalveolar length was defined as the distance between the reference points on the alveolar ridges on both sides of the maxilla, while the palatal arch depth was calculated as the linear distance from the intersection of the hard palate to the interalveolar line. Similarly, the maxillo-palatal arch angle was described as the angle formed by the lines drawn from the interpalatal fusion point to both crests of the alveolar arches, allowing for the evaluation of the three-dimensional conformation of the maxilla. These measurements were reported by Alkhader *et al.*¹³ and were selected for the present study because of their importance in identifying transverse maxillary deficiencies, a characteristic closely related to atresia. The diagnosis of maxillary atresia was determined using an interalveolar length (IAL) of less than 34.1 mm as a cutoff point, a value defined based on the median of the analyzed sample, given that there is no universally established threshold for this measurement in the scientific literature.

The dimensions of the upper airway were evaluated using specific tools in the EZ3D-i software (E-Woo Technology, Korea), considering the cross-sectional area, total volume (TV), and minimum area (MA) of the nasopharynx and oropharynx. The mid-sagittal plane was established as the reference plane; subsequently, the airway was segmented manually and automatically, delimiting the region from the posterior edge of the hard palate to the most anterior-inferior point of the second cervical vertebra. From this segmentation, linear and three-dimensional measurements were obtained using the software's "Airway Analysis" tool. The resulting data were exported for statistical analysis, ensuring an accurate, detailed, and reproducible assessment of upper airway dimensions in the pediatric population.

In the pediatric population, the reference values for the minimum area and total volume of the upper airway show great variability and are not clearly standardized. It has been suggested that a minimum area of less than 120 mm² and a total volume of less than 9 cm³ could reflect a size reduction, while values equal to or greater than these would be considered within the normal range. This wide variability highlights the importance of evaluating each case individually and in context.

To carry out the measurements of each variable of interest, the researcher received training and was standardized by an expert responsible for this study, who was considered the reference standard. Initially, an intra-observer assessment (ICC=1.0) was performed, followed by an inter-observer assessment (ICC=0.925-1.0), using the intraclass correlation coefficient (ICC) for quantitative variables.

The obtained data were analyzed using descriptive statistics, using measures of central tendency, dispersion, frequencies, and percentages. For inferential analysis, Student's t-tests were applied to compare gender differences in variables corresponding to maxillary atresia, which had a Gaussian distribution. On the other hand, upper airway variables did not follow a Gaussian distribution, so the comparison was made using the Mann-Whitney U test. Additionally, the correlation between the dimensions of the upper airway and the dimensions of the palate was analyzed using Spearman's correlation coefficient, all using IBM® SPSS® v.25 statistical software, considering a significance level of less than 0.05.

RESULTS

An initial sample of 74 patients was obtained, of whom 37 were diagnosed with skeletal class II and included in the statistical analysis. The distribution by gender was 51.4% women and 48.6% men, with a mean age of 8.78 ± 1.38 years.

The ANB angle showed an overall mean of $7.61 \pm 1.47^\circ$. Women had slightly higher values ($7.82 \pm 1.54^\circ$) compared to men ($7.38 \pm 1.41^\circ$), suggesting a greater anteroposterior discrepancy between the maxilla and mandible in women. Significant variability was observed in the palate measurements, reflecting anatomical and morphological differences among the assessed pediatric patients (Figure 1). The mean values for PIL, PAD, and MPAA are summarized in Table 1, with no differences identified between gender, suggesting that this variable does not significantly influence the palatal dimensions analyzed.

Table 1. Comparison of palate measurements between genders

Palate	Mean, SD	Women (Mean, SD)	Men (Mean, SD)	<i>p</i> *
PIL	34.5 ± 2.97	33.9 ± 2.7	33.7 ± 2.4	0.84
PAD	9.09 ± 1.87	8.8 ± 1.8	8.8 ± 1.9	0.90
MPAA	126 ± 8.90	125.9 ± 9.7	125.8 ± 10.3	0.97

PIL: palatal interalveolar length, PAD: palatal arch depth, MPAA: maxillo-palatal arch angle, SD: standard deviation, **p*-value obtained from Student's t-test



Figure 1. CBCT coronal sections showing palate measurements in different participants, illustrating the anatomical and morphological variability of the palate.

To diagnose maxillary atresia, an interalveolar length value of less than 33.8 mm was used. Of the 37 participants, 23 were diagnosed with maxillary atresia, with women accounting for the highest percentage at 73% and men accounting for 27% (Table 2). Linear and three-dimensional parameters were analyzed in the upper airway, with wide variability observed among patients. In linear measurements, the nasopharynx and oropharynx showed values ranging from normal dimensions to obvious reductions, while in three-dimensional measurements, wide dispersions were identified in total volume and minimum area, the latter considered the point of greatest airway constriction. Overall, airway dimensions did not show a uniform pattern of decrease or significant differences between gender, which is consistent with what has been previously described in the literature (Table 3).

Table 2. Frequency of maxillary atresia by gender (PIL <33.8 mm)

Atresia	Gender	Frequency	Percentage of Total	Cumulative Percentage
No	Female	6	16.2%	16.2%
	Male	8	21.6%	37.8%
Yes	Female	13	35.1%	73.0%
	Male	10	27.0%	100.0%

PIL: palatal interalveolar length

Table 3. Comparison of upper airway (UAW) measurements between genders

UAW	Overall	Female	Male	<i>p</i> **
Nasopharynx*	14.6 (5.5)	14.6 (4.5)	13.9 (3.3)	0.46
Oropharynx*	10.4 (4.5)	10.9 (4.4)	9.7 (4.8)	0.55
TV*	9.5 (5.4)	9.2 (3.5)	8.85 (6.5)	0.93
MA*	135 (7.7)	127.0 (61.2)	111.0 (71.9)	1.00

TV: total volume, MA: minimum area, *Data expressed as mean (interquartile range), ** *p*-value obtained from the Mann Whitney U test

Three-dimensional reconstructions of the upper airway showed variations in dimensions, reflected in changes in airflow between adequate conditions and significant reductions. The areas of narrowing were identified by colorimetric analysis, where red tones indicated areas of smaller cross-sectional area and greater constriction, and green and blue tones indicated regions with normal or expanded dimensions. This color coding allows for qualitative visualization of the spatial distribution of respiratory flow (Figure 2).

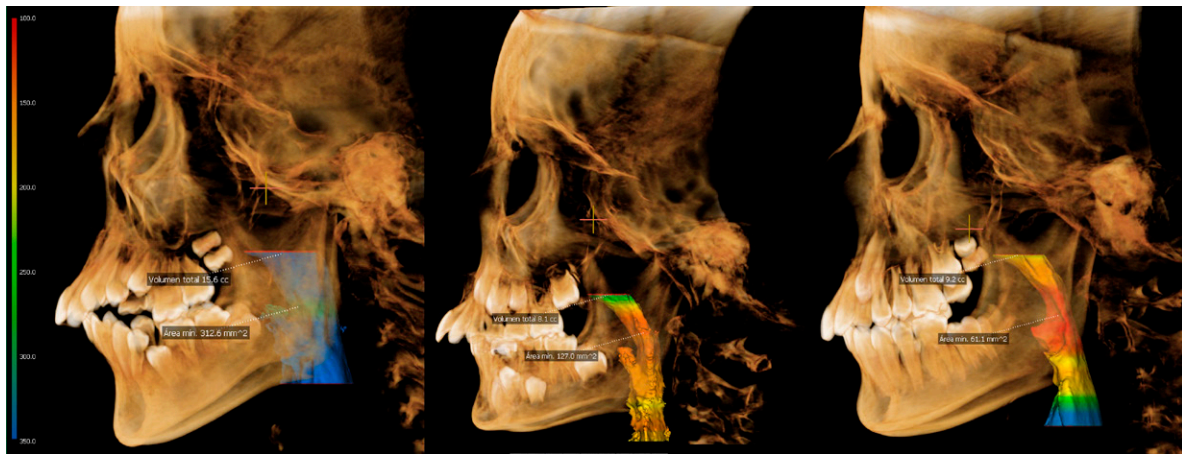


Figure 2. Three-dimensional reconstruction of the upper airway showing differences in volume, minimum area, and airflow observed among study participants.

A significant correlation ($p = 0.033$) was found between the depth of the palatal arch and the total volume of the upper airway, suggesting that this palatal dimension could be associated with a change in airway volume. This finding highlights the importance of considering maxillary morphology in the evaluation of pediatric respiratory disorders (Table 4).

Table 4. Correlation analysis

		Nasopharynx	Oropharynx	TV	MA
PIL	Spearman's Rho	0.003	0.17	0.20	0.25
	<i>p</i>	0.98	0.29	0.22	0.12
PAD	Spearman's rho	0.05	0.30	0.35	0.11
	<i>p</i>	0.76	0.07	0.03	0.49
MPAA	Spearman's rho	-0.06	-0.22	-0.24	0.001
	<i>p</i>	0.72	0.17	0.14	0.93

PIL: palatal interalveolar length, PAD: palatal arch depth, MPAA: maxillo-palatal arch angle, TV: total volume, MA: minimum area, *Correlation is significant at the 0.05 level (bilateral)

DISCUSSION

The findings of this study coincide with those reported by Perrotti *et al.*¹⁴ who, when analyzing the relationship between craniofacial sagittal patterns and upper airway dimensions in 99 CBCTs of adult patients, found significant differences in the oropharynx, hypopharynx, and

total volume, showing smaller dimensions in women with skeletal class II. In the present study, conducted in growing patients with an average age of 9 years, males had a higher frequency of maxillary atresia, with 40% compared to 38.2% of females, both accompanied by a predominant volumetric reduction in the nasopharynx.

Within this study, three cases with atypical values in the minimum upper airway area were identified: two males without maxillary atresia and one female with this condition, all of whom had a greater-than-average palatal arch depth. However, contrary to expectations, this showed a nasopharynx, oropharynx, and total volume in the 75th percentile and a minimum area in the 95th percentile, suggesting that, in some cases, maxillary atresia does not necessarily imply a reduction in the airway, which contrasts with what has been reported in the literature¹⁵.

In the correlation analysis between palate measurements and both linear and three-dimensional dimensions of the upper airway, there is a significant correlation between the reduction in the transverse dimension of the maxilla, evaluated by interalveolar length, and the total volume of the upper airway, which could directly impact child growth and development, as well as the functions of the stomatognathic system. This contrasts with the findings of Alkhader *et al.*¹³ who found a weak correlation between these variables and suggested using palate measurements as a predictor of airway dimensions.

During the evaluation of the upper airways, alterations in the maxillary sinuses and nasal turbinates were identified, such as turbinate hypertrophy, thickening of the sinus mucosa, partial or total occupation of the maxillary sinuses, and nasal septum deviations. These findings coincide with those reported by Dikici *et al.*¹⁶ who pointed out that such alterations are significantly associated with nasal airway obstruction, which affects respiratory function.

Similarly, Sleiman and Saadé¹⁷, as well as Cárdenas *et al.*¹⁸, respectively report that nasal alterations impact craniofacial growth in general and the shape of the nasomaxillary complex, reflecting the importance of a comprehensive evaluation in developing patients, given the anatomical impact it can have (Figure 3). Similarly, a study by Bruno *et al.*¹⁹ observed that half of the CT scans obtained for orthodontic reasons showed incidental findings in the maxillary sinus, with 68.2% presenting opacification of the maxillary sinuses. Similarly, Gutiérrez *et al.*²⁰ reported a high frequency of inflammatory findings and mucosal changes in the maxillary sinuses, in agreement with the results of the present study, which also showed a notable prevalence of sinus alterations even in asymptomatic patients^{19,20}.

Finally, it is important that future research stratify Class II patients according to maxillary, mandibular, or combined contribution, as this differentiation could reveal significant differences in results. It would also be advisable to consider other craniofacial and functional factors that may influence the upper airway, as well as to perform longitudinal analyses to evaluate changes during growth. These considerations would allow for a more detailed and accurate analysis of the relationship between skeletal morphology and respiratory function in the pediatric population, optimizing clinical interpretation and future treatment planning.

CONCLUSION

Early identification of maxillary atresia and upper airway alterations in patients with skeletal class II is essential to prevent respiratory complications and promote proper craniofacial development. In this study, measurements of both structures showed high variability, with no significant differences between genders or a clear relationship between maxillary atresia and airway dimensions, suggesting the influence of other factors on their morphology and

function. The use of CBCT allows for detailed three-dimensional evaluation, improving diagnosis and treatment planning. Its integration into clinical practice facilitates the detection of alterations and more accurate therapeutic decision-making for maxillary orthopedic treatment.

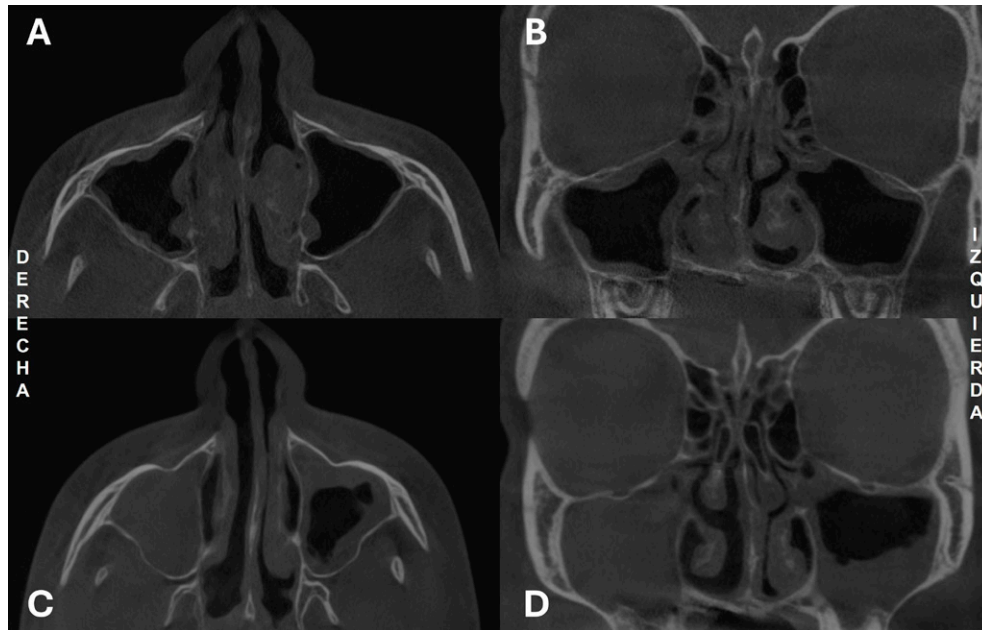


Figure 3. Tomographic sections. A-B. 8-year-old male patient, showing thickening of the mucosa in both maxillary sinuses and a significant reduction in nasal air space due to hypertrophy of the nasal turbinates. A. Axial. B. Coronal. C-D. 11-year-old female patient showing total occupation of the right maxillary sinus, mucosal thickening in the left maxillary sinus, and hypertrophy of the left nasal turbinate, accompanied by a slight deviation of the nasal septum. C. Axial. D. Coronal.

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