Is there a correlation between airways dimensions and transversal dental distances in children with different growth patterns?

ABSTRACT

Aims: The aim of this study was to evaluate the correlation between airway dimension sizes, transversal dental distances, and craniofacial growth pattern.
Study design: Retrospective observational study
Place and Duration of Study: Sample: Department of Restorative Dentistry, Division of Orthodontics, School of Dentistry, between March 2018 and December 2023.
Methodology: A sample of 271 children aged between 7 and 10 years was evaluated. Airways and facial angles were measured to determine the pattern of facial growth. Maxillary transverse dimensions were assessed using plaster study models. Two groups were delimited with 30 individuals each according to the most extreme facial measurements: patients with horizontal and vertical growth tendency. The correlations between nasopharynx and oropharynx size with maxillary intercanine and intermolar distances in different craniofacial growth patterns were evaluated.
Results: Vertical group presented significantly smaller dimensions of the nasopharynx and maxillary intercanine distance. Oropharynx dimension and intermolar distance are similar for both vertical and horizontal patterns. There was no significant correlation between nasopharynx and oropharynx size and maxillary intercanine and intermolar distances.
Conclusion: Patients with a vertical growth pattern have smaller nasopharyngeal dimensions and greater anterior maxillary atresia than patients with a horizontal growth pattern. Oropharyngeal dimensions and maxillary intermolar distance are similar in different growth patterns.

Keywords: *Cephalometry, Airway remodeling, Growth and Development, Nasopharynx, Vertical dimension*

1. INTRODUCTION

Facial growth theories, such as Moss's Functional Matrix theory [1], place correct nasal breathing as a promoter of adequate growth and development of the craniofacial complex, interacting with other functions, such as chewing and swallowing. Furthermore, the relationship between nasal breathing and the development of palatal width and maxillary sinus size has significant clinical implications. Proper nasal breathing exerts a positive influence on palatal expansion and maxillary sinus growth, both of which are essential for the harmonious development of the craniofacial complex. For this reason, the development of chronic mouth breathing, caused or not by airway obstruction, may represent an etiological factor for the occurrence of morphological changes, negatively influencing the development of the craniofacial complex and dentoalveolar structures [2].

Studies point to an increased prevalence of Class II skeletal malocclusions, posterior crossbite and anterior open bite in mouth breathing children [3]. Such facial development problems occur due to backward and downward rotation of the mandible, with a consequent increase in the maxillary-mandibular plane angle and narrowing of both maxillary and mandibular arches at the level of the canines and first molars [4,5]. Mandibular retrusion has been related to a more retruded position of the hyoid bone, which in turn alters the morphology of the airways. Some skeletal characteristics such as maxillary and mandibular retrusion and vertical maxillary excess in hyperdivergent individuals lead to an anteroposterior narrowing of the airways [6].

In addition to the anteroposterior and vertical disorders, the maxillary transversal contraction, known as maxillary atresia, are directly related to a breathing pattern. Ravelo et al. (2020) [7] compared the three-dimensional measurements of pre- and post-rapid maxillary expansion (RME) patients and noted an increase in nasopharyngeal dimensions. Recent study [8] have demonstrated that the dimensions of the pharyngeal morphology may vary according to craniofacial growth and therapies with functional appliances. Hence, previous studies [9,10] have shown that performing RME in cases of maxillary atresia can favorably alter the breathing pattern by expanding the dimensions of the nasal cavity.

Therefore, the purpose of this study was to investigate the correlation between the dimensions of the naso- and oropharyngeal airways in the anteroposterior and transverse directions, analyzing the maxillary intercanine and intermolar distances in children with short and long faces. The null hypothesis was tested that there is no difference in the dimensions of the airways (oropharynx and nasopharynx) in the anteroposterior and transverse directions, with no correlation in individuals with extreme vertical and horizontal growth patterns.

2. MATERIAL AND METHODS

The retrospective convenience sample was obtained from the files of the Department of Orthodontics, Faculty of Dentistry, XXXXXXXXXXX (XXXX) and consisted of 271 lateral cephalometric radiographs and plaster models at treatment onset of children aged 7 to 10 years. This study was approved by the Research Ethics Committee (CAAE: 12729519.6.0000.5149). The selection criteria were initial lateral cephalometric radiographs and dental study models of children between 7 and 10 years of age, complete eruption of all maxillary incisors and first molars, dental study models in good condition, without tooth fractures; and, absence of dental anomalies.

Lateral cephalometric radiographs were used to measure both the craniofacial growth pattern and the dimensions of the airways. The Radiocef Studio program (Radio Memory, Belo Horizonte, Brazil) was used for cephalometric tracings to measure the airways and angles to assess the children's facial types.

A sample calculation was performed for an alpha significance level of 5% and a beta of 20%, to reach a test power of 80% and detect a minimum difference of 1.30 mm and standard deviation of 1.71 mm in the oropharynx variable [11], thus verifying the need for 28 individuals per group. This way, from this initial sample, patients were divided into 2 groups of 30 patients according to facial growth pattern. Group 1, consisting 14 males and 16 females, with a vertical growth pattern, aged between 7.52 and 9.6 years. Group 2, consisting 18 males and 12 females, with a horizontal growth pattern, aged between 7.64 and 9.7 years.

The methodology used to classify individuals as those with a tendency to vertical or horizontal growth was in accordance with that used by Neves et al. (2005) [12], adding the measure of the Ricketts Facial Axis Angle. The sample of these groups were formed from the individuals with the most extreme measures of the entire sample. For this, the 271 individuals were listed in ascending order of the measurements obtained from FMA, SN-GoGn and NS-Gn, and the sum of the first 30 patients in this list were separated into the Horizontal group, with smaller facial angles. The last 30 patients who had the sum of the larger Facial Angles measurements, were assigned to the Vertical group. For the BaN-PtGn Angle (Ricketts Facial Axis) the principle was the same, but in this case the listing was organized in descending order, since this magnitude is inversely proportional to the others used to determine the pattern of facial growth (Figure - 1A).

Pharyngeal measurements were performed by measuring the linear distance, in millimeters, between the marked points, as shown in Figure – 1B, where the measurement of the nasopharynx was performed by establishing a point on the upper portion of the dorsum of the soft palate where it was as close as possible to the posterior wall of the nasopharynx (Nfp), and the second point was marked at the shortest distance from the first (Nfa). The oropharynx was measured by establishing a point at the intersection between the dorsum of the tongue and the external cortical bone of the mandible (Bfa) and a second point at the shortest distance from the first, also at the intersection between the external cortical bone of the mandible and the oropharynx (Bfp), as recommended by McNamara Jr. (1984) [13].

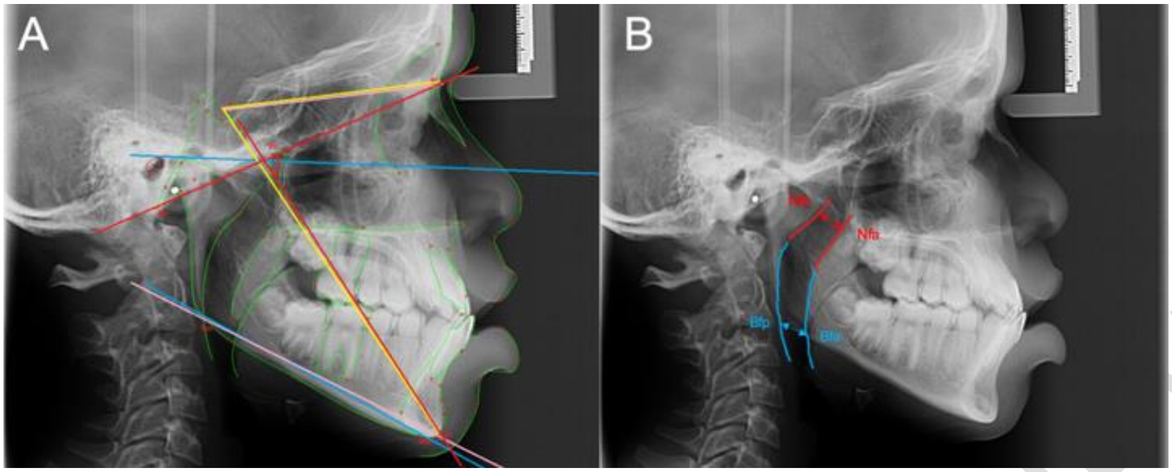

Figure 1: Anatomic tracement with cephalometric measurements [**A.** FMA: angle from Frankfurt horizontal plane and mandibular plane (blue); GoMe: NS-Gn (Y growth axis): angle from SN e SGn lines (yellow); SN-GoGn: angle from SN line and mandibular plane GoGn (pink); BaN-PtGn (Ricketts Facial Axis): angle from BaN line and PtGn facial axis (red). **B.** In red, measurement of the nasopharynx upper portion of the dorsum of the soft palate the posterior wall of the nasopharynx (Nfp), and the second point was marked at the shortest distance from the first (Nfa). In blue, measurement of the oropharynx at the intersection between the dorsum of the tongue and the external cortical bone of the mandible (Bfa) and a second point at the shortest distance from the first, also at the intersection between the external cortical bone of the mandible and the oropharynx (Bfp).]

Dental study models were used to measure the intercanine and intermolar distances of the maxillary arch. For this, they were positioned on a flat surface and the central fossa of the maxillary first permanent molars were used as a reference, for the calculation of the intermolar distance, and the cusp tips of the canines for the intercanine distance. Measurements were performed by a calibrated examiner (N.D.L.), who used a digital caliper with a precision of 0.01mm (Mtx, Shanghai, China).

2.1 Method error

Fifty-five pairs of dental study models and 55 randomly selected radiographs were remeasured by the same examiner (N.D.L.). The casual error was determined using the Dahlberg's formula, ($S^2=\Sigma d^2/2n$), and the systematic error with dependent *t* tests, at $P < 0.05$.

2.2 Statistical analysis

The Shapiro-Wilk normality test was performed to verify the normality of the data in the cephalometric variables. The independent t test was used to verify the compatibility of the groups in relation to the initial ages. The chi-square test was also used to verify gender distribution between the vertical and horizontal groups.

In the sample with normal distribution, Pearson's correlation test was used to assess the existence of a correlation between the intercanine and intermolar distances, the size of the upper and lower airways, and the cephalometric variables related to the patient's growth pattern. When there was no normal distribution, the existence of correlation between the variables was assessed using the Spearman correlation test.

For the comparison between the vertical and horizontal groups in the variables related to the growth pattern, intercanine and intermolar distances and size of the upper and lower airways, the independent t test was used when the data distribution was normal. In cases where there was no normal distribution, the intergroup comparison was performed using the non-parametric Mann-Whitney test.

All tests were performed with the BioStat program (BioStat 5.3, Gent, Belgium), adopting a significance level of 5%.

3. RESULTS

Random errors ranged from 0.50 (Nasopharynx) to 1.26 (FMA) and none of the variables showed significant systematic error.

In assessing the normality of the data using the Shapiro-Wilk test, it was found that the nasopharynx, oropharynx, FMA and Facial Axis variables did not present normal distribution in the horizontal group. The vertical and horizontal groups were compatible in terms of mean initial age and gender distribution (Table 1).

Table 1 – Baseline characteristics.

Variables	Vertical group		Horizontal group		
	Mean/Median	SD/ IR∞	Mean/Median	SD/ IR∞	p
Age*	8,56	1,04	8,67	1,03	0,7094
NSGn*	73,70	2,36	62,17	2,46	0,0000
SN-GoGn*	43,67	2,06	26,63	2,68	0,0000
FMA**	35,00	4.87	20,00	5.73	0,0000
Facial axis**	83,00	3.11	96,00	2.76	0,0000
	Man		Woman		p
Vertical***	14		16		0,3006
Horizontal***	18		12		

∞ SD, standard deviation; IR, Interquartile range; * Independent t-test; ** Mann-Whitney test; ***Chi-square test

The vertical group presented a significantly smaller size of the nasopharynx and intercanine distance compared to the horizontal group (Table 2).

Table 2 – Comparison of distances (in mm) between vertical and horizontal groups.

Variables	Vertical group n=30		Horizontal group n=30		p
	Mean/Median	SD/ IR∞	Mean/Median	SD/ IR∞	
Intercanine distance*	31,80	2,89	33,80	2,58	0,0064
Intermolar distance*	45,20	2,76	46,23	3,29	0,1924
Nasopharynx**	5,00	4.15	7,00	3.61	0,0436
Oropharynx**	10,50	5.35	10,00	5.76	0,4119

∞ SD, standard deviation; IR, Interquartile range; *Independent t test; **Mann-Whitney test

The results of the correlation tests between the assessed variables showed a significant positive correlation between: upper intercanine and upper intermolar distances; oro and nasopharyngeal sizes; and facial axis angle and upper intercanine distance, and nasopharyngeal and oropharyngeal sizes. Furthermore, a significant negative correlation was found between: the NS-Gn angle and the upper intercanine and intermolar distance; the SN-GoGn angle and the upper intercanine distance; and, the FMA angle and the upper intercanine distance (Table 3).

Table 3 – Results of the correlation test among cephalometrics, dental and airways variables.

	Intercanine distance	**Intermolar distance**	**Nasopharynx**	**Oropharynx**	**NS-Gn**	**SN-GoGn**	**FMA**	**Facial Axis**
Intercanine distance	**X**	**r= 0,62* p= 0,000**	**r= 0,07* p= 0,243**	**r= 0,01* p=0,824**	**r= -0,23 p=0,0002**	**r= -0,20 p=0,0009**	**r= -0,15 p=0,0142**	**r= 0,24* p=0,000**
Intermolar distance		**X**	**r= 0,39* p= 0,530**	**r= -0,00* p=0,947**	**r= -0,12* p=0,047**	**r= -0,11* p=0,070**	**r= -0,01* p=0,812**	**r= 0,08* p=0,200**
Nasopharynx			**X**	**r= 0,18* p=0,004**	**r= -0,11* p=0,063**	**r= -0,09* p=0,122**	**r= -0,06* p=0,299**	**r= 0,21* p=0,001**
Oropharynx				**X**	**r= -0,06* p=0,355**	**r= 0,06* p=0,298**	**r= 0,00* p=0,998**	**r= 0,13* p=0,028**

* Spearman test correlation

4. DISCUSSION

The use of teleradiographs to assess the airways has been used quite frequently and in a recent study [14] it was found that although tomography showed greater variability in the results of acquired airway sizes, teleradiographs showed a moderately high correlation with CT scans between areas and volumes of the airways. Therefore, it is considered possible that the research conducted utilizing cephalometric radiographic images is capable of identify a pattern in the behavior of the studied structures, since this type of study has been carried out by other authors [15,16]. Cephalometric variables were selected due to their convenient and routinely use by orthodontists to classify facial growth pattern, as previous [12]. The findings of the present study showed smaller nasopharyngeal and intercanine distances of the Vertical group (hyperdivergent) compared to horizontal group (hypodivergent). Thus, the null hypothesis was rejected.

The upper nasopharyngeal distance was previously related to increase with age [17]. In our study children with similar age, close to eight and a half years, were included to mitigate the age effect. The result of smaller nasopharyngeal width in hyperdivergent individuals agrees with previous studies [11,18]. Despite an adenoid hypertrophy may possible cause narrower nasopharyngeal widths, the presence of hypertrophic adenoids enlargement seems to be more pronounced in the hyperdivergent face after eight years of age [19]. Hence, upper nasopharyngeal distance in children is more representative of the bony nasopharynx than the soft tissue changes within it [20]. Thus, measurement of upper nasopharynx has limited effects of adenoids that could mislead the correlation of bone growth pattern. Besides, Joseph et al. (1998) [21] suggested that the difference is due to a relative bimaxillary retrusion presented by the hyperdivergent group. This is in accordance to the results of Facial Axis found that expresses the ratio of facial height to facial depth. The Vertical group had lower values of this angle indicating an anteroposterior retrusion compared to Horizontal group.

Contrary to the results of upper nasopharynx dimension, the lower oropharynx widths were similar between the groups with vertical and horizontal growth pattern. This observation suggests a limited association between the lower airways and the facial type observed in our study, which is consistent with previous studies findings [6,22]. However, a different outcome was found by Singh Tarkar et al. (2016) [23], who noted wider dimensions of the lower airways in patients with a horizontal growth pattern. These patients also had the hyoid bone positioned further away from the mandible compared to the vertical group. One possible explanation for this finding is the anterior position of the hyoid bone, which is also observed in hyperdivergent individuals and contributes to an increase in oropharyngeal width [24]. Furthermore, since our study included extreme cases hyper- and hypodivergent children, who are more likely to exhibit mouth breathing [20,25], it was expected that the upper nasopharynx dimensions would decrease [11]. Nonetheless, the impact on the lower oropharynx dimensions in these cases was not significant, as they receive a compensatory amount of air through the oral airways.

A positive correlation was observed between oro- and nasopharynx. This observation suggests that the narrowing of the airway could occur uniformly, affecting both the upper and lower regions. Nevertheless, the correlation coefficient was found to be very low, indicating the possibility of other factors at play. One such explanation is the prevalence of individuals with hypertrophy of the tonsils, which would lead to limited narrowing of the oropharynx. Another possibility is the presence of hypertrophy of the adenoids, which would cause narrowing solely in the Nasopharynx, as previously mentioned [23], with similar results.

In the Vertical growth group, the intercanine distance decreased by 2mm. According to Mani et al. (2015) [26], the vertical facial growth pattern in children influences the transversal morphology of anterior upper arch, resulting in a triangular geometry. In this regard, triangular palates in upper arches has been considered with more several atresia compared to strict uniform palates [27]. This finding is in line with the negative correlation between the intercanine distance and all measurements related to facial growth pattern. Therefore, the more vertical the patient, the smaller the intercanine distance, indicating a higher likelihood of atresia in the anterior portion of the palate. Consequently, children with a vertical growth pattern may be indicative of a palate that tends towards a triangular shape.

The intermolar distance was similar between both groups. Besides, a positive correlation between intercanine and intermolar distances had the highest correlation coefficient found by this study (0,62). This data suggests that when there is a maxillary atresia in the region of upper canines, an atresia within the posterior region may occur due to a smaller intermolar distance. For the intermolar distance, there was a significant correlation only for one of the four magnitudes studied to characterize the facial growth pattern, and even so a very low correlation, which would not allow us to state that a child with a vertical growth pattern presents a strong tendency to an atretic palate in the posterior region, corroborating with previous findings [28]. As hyperdivergent children have a greater tendency to be mouth breathers [20,25], this could be an etiological factor for maxillary atresia, since mouth breathers have downward and backward posture of the tongue [29] and greater pressure on the external facial muscles [30].

To the best of our knowledge, this is the first study that correlates airway anteroposterior distances to maxillary transversal widths in children. In this study, there was no significant correlation between the transversal dimensions of the maxilla and airway widths. A recent study in adolescents [31] found a positive and sex-dependent low correlation between maxillary length and upper nasopharyngeal airway dimension. This contradictory result may have occurred due to analysis made in children with maxillary transversal expansion still on development and less time period in contact to facial muscles. The two-dimensional analysis used to measure the airways anteroposterior distance may be limited, and possibly would not be able to detect lateral narrowing of the airspace even if it were present. Thus, as the results of the present study did not show a correlation between intercanine and intermolar distances and the dimensions of the airways, they suggest that the dimensions of the airways correlate only with the facial growth pattern. Future studies investigating the relationship between sexual dimorphism and changes during maxillary expansion interventions should be explored to gain further insights between sagittal and transverse growth patterns and airway dimensions.

5. CONCLUSION

In this study, we found a tendency for the nasopharynx and intercanine distance to have a smaller dimension in individuals with vertical growth compared to those with horizontal growth. There was a very low correlation between the dimensions of the nasopharynx and oropharynx between individuals, which suggests that the nasopharynx presents greater alterations when compared with the type of facial growth pattern in children. The facial axis was the only growth pattern variable that correlated with the size of the nasopharynx and oropharynx. Furthermore, there was a negative correlation between the intercanine distance and the facial growth pattern and between the intermolar distance and the variable of facial growth pattern NS-Gn.

ETHICAL APPROVAL

This study was conducted in accordance with all the provisions of the local human subjects oversight committee guidelines and policies of: XXXXXXXXXXXXXXXXXXXXXXXXX. This study protocol was reviewed and approved by [committee name and affiliation], approval number [12729519.6.0000.5149].
All authors hereby declare that all experiments have been examined and approved by the appropriate ethics committee and have therefore been performed in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki.

Disclaimer (Artificial intelligence)

Option 1:

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

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