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Morphometric growth changes of the nasopharyngeal space in subjects with different vertical craniofacial features

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Introduction: The purpose of this study was to morphometrically investigate the growth pattern of the adenoids in growing subjects with hyperdivergent and hypodivergent vertical craniofacial features. **Methods:** In this retrospective study, we used a longitudinal sample of lateral cephalometric radiographs of 28 hyperdivergent and 30 hypodivergent subjects from 4 to 13 years of age. The radiographs were obtained from the American Association of Orthodontists Foundation Craniofacial Growth Legacy Collection. Measurements were made using digital tracings of the lateral cephalograms and point distribution models. Mixed-model analyses were used for statistical analysis. **Results:** The mean distance between the sphenoid bone and the posterior nasal spine increased up to 5.3 mm over a 9-year span (95% CI, 4.1-6.5 mm; $P <0.001$). Furthermore, the mean distance between the sphenoid bone and the posterior nasal spine differed significantly ($P = 0.029$) between facial types; it was consistently greater (1.8 mm; 95% CI, 0.2-3.3 mm) in the hyperdivergent group. The nasopharyngeal airway area showed a trend to increase with age up to 12-fold ($P <0.001$). A significant interaction ($P = 0.004$) was found between age and facial type. Assessment of the adenoid shapes showed greater convexities in the hyperdivergent group, which were observable from an earlier age and for a longer duration. **Conclusions:** Clear differences in the morphometric growth pattern of the adenoids were found between facial types. Evaluation of adenoid shapes showed more prominent convexities that lasted longer in the long facial types than in the short facial types. (Am J Orthod Dentofacial Orthop 2016;150:451-8)

Hypertrophic adenoids have been shown to be a significant risk factor for pediatric sleep breathing disorders, such as obstructive sleep apnea (OSA).[1-4] Several studies have shown that restriction of the upper airways caused by enlarged adenoids, and hence mouth breathing, may also be directly linked to specific craniofacial morphologies such as the long face syndrome.[5-8] A study conducted on monkeys, where varying degrees of nasal respiratory obstruction were

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simulated, further supported these findings.[9] Although variations exist, the typical characteristics of this long facial morphology include increased anterior facial height, incompetent lips, steep mandibular plane angle, anterior open bite, and retrognathic mandible.[4-7,10] The term "long face syndrome" encompasses a variety of facial types with specific clinical and cephalometric features including the so-called adenoid face[10] that has been associated with mouth breathing and OSA.[7] Although various theories have been postulated on how nasopharyngeal restriction alters craniofacial morphology, this is still a matter of debate. It is unclear whether alterations in the facial skeleton predispose a person to OSA, or whether these alterations are caused by OSA.[7]

Results from investigations into the growth pattern of the adenoid tissues have also been somewhat controversial. Several findings from the early to mid-20th century, including Scammon's curves of systematic growth, have demonstrated that lymphatic tissues undergo rapid growth from infancy until a peak about 10 to 13 years of age.[8,11-13] Subsequent regression in maturity follows. On the contrary, research in this field in later years generally proposed a different pattern of growth where

adenoids were seen to hypertrophy as early as 2 years of age but generally peaked during the preschool and early school years, or around 4 to 6 years of age.[12,14-17] Adenoidal regression until adulthood was then noted. A few studies observed a slight and temporary enlargement in the adenoids about 11 years of age and suggested that it was due to the influence of sex hormones at puberty.[15-17] In this research, however, adenoid changes were investigated using either only cephalometric methods or a subjective assessment of adenoid hypertrophy, with limited information regarding the actual changes of adenoid shapes over time.

The purpose of this study was to morphometrically investigate the growth pattern of the adenoids in growing subjects with long and short faces to obtain new insight into the association between adenoid growth and craniofacial morphology. We hypothesized that the growth pattern of the adenoid tissues would follow those described in the literature.[15-17] That is, peak adenoid size would be reached at approximately 4 to 6 years of age followed by regression until approximately 10 to 11 years of age. A brief period of adenoid enlargement would be expected about 11 years of age with subsequent regression to the size seen in maturity. Furthermore, morphometric analysis was expected to show prominent convexities on the anteroinferior surface of the adenoids during peak growth at 4 to 6 years of age, followed by flattening of this surface corresponding to reduction in the size of the adenoids. Increased adenoid growth and more prominent convexities were hypothesized in the hyperdivergent group compared with the hypodivergent group.

MATERIAL AND METHODS

A convenience sample of lateral cephalometric radiographs was obtained from the American Association of Orthodontists Foundation (AAOF) Craniofacial Growth Legacy Collection Web site.[18] At the time of sample selection, 696 participants with approximately 8700 corresponding lateral cephalograms were available online for analysis.

The sella-nasion–mandibular-plane angle (SN-MP) was measured for each subject at 13 years of age to define the vertical craniofacial pattern. It has been shown that the mean value of the SN-MP angle is 32° with a standard deviation of 5°.[19] For the purpose of this research, subjects with an SN-MP angle greater than 39.5° and less than 24.5° (1.5 SD above and below the mean) were selected as the hyperdivergent and hypodivergent groups, respectively. Both groups were then checked for the following inclusion criteria: (1)

Table I. Number of radiographs available and missing or excluded from 4 to 13 years of age according to facial type

Age (y)	Available radiographs (n)	Missing or excluded radiographs (n)	Available radiographs (n)	Missing or excluded radiographs (n)
4	9.0	19.0	13.0	17
5	19.0	9.0	19.0	11
6	25.0	3.0	25.0	5
7	28.0	0.0	26.0	4
8	27.0	1.0	28.0	2
9	22.0	6.0	20.0	10
10	24.0	4.0	25.0	5
11	25.0	3.0	26.0	4
12	22.0	6.0	24.0	6
13	25.0	3.0	21.0	9
Total	226.0	54.0	227.0	73

radiographs available for download from the AAOF Web site with at least 8 lateral cephalograms between the ages of 4 and 13 years, (2) radiographs of adequate quality (at least 300 dpi), and (3) nasopharynx, adenoids, and soft palate clearly visible. The exclusion criterion was poor radiographic quality, making identification of the nasopharynx, adenoids, or soft palate difficult.

The required sample size was estimated by using previous data showing the variability of the nasopharyngeal area in a cohort of healthy participants.[20] In this study, we aimed to detect a medium-to-large effect size (Cohen's d $\geq$ 0.2) using a repeated-measurements study design. The correlation among repeated measurements was estimated at 0.3. To detect this effect size, and setting α error to 0.05 and β error to 0.20, we estimated that about 34 participants per group were needed.

From a pool of 453 lateral cephalograms, 58 participants (30 hypodivergent, 28 hyperdivergent) fulfilled the selection criteria and were included in this study. Table I shows the number of radiographs that were available from 4 to 13 years of age, based on facial type.

All lateral cephalograms available from ages 4 to 13 were retrieved from the online collection for each participant. The age at which these radiographs were taken was rounded to the nearest full year of chronologic age. If multiple lateral cephalograms had been taken in 1 year, only the radiograph taken nearest to each full year was measured. All downloaded images were scaled according to the recommendations of the AAOF.

One investigator (J.E.P.) performed all digital tracings using a custom-made script in MatLab (The MathWorks, Inc, Natick, Mass) (R21012b), which allowed the conversion of digital landmarks to Cartesian coordinates so that morphometric shape analysis could be conducted. On each radiograph, landmarks were identified and