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Article

Assessment of nasopharyngeal airway volume in pediatric patients with adenoid hypertrophy by cone-beam computerized tomography.

Volumen de la vía aérea nasofaríngea en pacientes pediátricos con hipertrofia adenoidea: evaluación por tomografía computarizada de haz cónico.

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Abstract: Objective: Adenoid hypertrophy is a disease whose most serious effect is the obstruction of the nasopharyngeal airway, leading to severe dentoskeletal deformities. The aim of this study was to determine the volume of the nasopharynx in patients with different grades of adenoid hypertrophy. Materials and methods: A retrospective study was conducted. One hundred and twenty-five cone beam computed tomographies of 8 to 12-year-old pediatric patients, obtained from the 2014-2017 database of the School of Dentistry of Universidad de San Martin de Porres, were selected. Romexis 3.6.0 software (PlanMeca®, Finland) was used. In order to make a diagnosis and determine the grade of hypertrophy (Grade 1= healthy, Grade 2= mild, Grade 3= moderate and Grade 4= severe) quantitative and qualitative methods were used; grades 2, 3 and 4 were considered pathological. The same software was used to determine the volume of the nasopharynx. Results: Grade 1 hypertrophy was 44%, mild 36,8%, moderate 13,6% and severe 5,6%, accounting for a pathological adenoid hypertrophy prevalence of 56%. The mean volume of the nasopharynx was 4.985, 3.375, 2.154 and 0.944cm^3 for grades 1, 2, 3 and 4, respectively. Conclusions: There is a high prevalence of pathological adenoid hypertrophy (56%). The volume of the nasopharynx decreases according to the severity of the adenoid hypertrophy.

Keywords: *Hypertrophy; adenoids; nasopharynx; cone-beam computed tomography; child.*

Resumen: Objetivo: La hipertrofia adenoidea es un una patología cuya repercusión más severa es la obstrucción de la vía aérea nasofaríngea, con graves consecuencias de malformaciones dento-esqueléticas. El objetivo del estudio fue determinar el volumen de la vía aérea nasofaríngea en pacientes con diferentes grados de hipertrofia adenoidea. Material y método: Se realizó un estudio retrospectivo, se seleccionaron 125 tomografías computarizadas de haz cónico de pacientes pediátricos de 8 a 12 años de edad obtenidas en la base de datos del 2014 al 2017 de la Facultad de Odontología de la Universidad de San Martín de Porres. Se utilizó el software Romexis 3.6.0 (PlanMeca®, Finlandia); para realizar el diagnóstico y determinar el grado de hipertrofia (Grado 1= sano, Grado 2=leve, Grado 3=moderado y Grado 4= severo) se utilizaron dos métodos, uno de evaluación cualitativa y otra cuantitativa; los grados 2, 3 y 4 fueron considerados como patológicos; para determinar el volumen de la vía aérea nasofaríngea se utilizaron las herramientas del mismo software. Resultados: La hipertrofia grado 1 estuvo constituida por el 44%, leve en el 36.8%, moderado en el 13.6% y severo en el 5.6%; constituyendo finalmente una prevalencia de hipertrofia adenoidea patológica del 56%. Las medias de los volúmenes de la vía aérea nasofaríngea fueron de 4.985, 3.375, 2.154 y 0.944 cm^3 para los grados 1, 2, 3 y 4 respectivamente. Conclusión: Existe una alta prevalencia de hipertrofia adenoidea patológica (56%), el volumen de la vía aérea nasofaríngea tiende a disminuir conforme a la severidad de la hipertrofia adenoidea.

Palabras Clave: *Adenoide; hipertrofia; nasofaringe; tomografía computarizada de haz cónico; niño.*

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INTRODUCTION.

The nasopharynx is an air-filled cavity that is part of the upper airway. It is surrounded by soft structures and abundant lymphoid tissue located in a greater amount in a structure called the adenoid, first described in 18681,2. There is a normal increase in adenoid size during the process of growth and development; however, when adenoids enlarge excessively, known as adenoid hypertrophy, mechanical obstruction of airflow occurs. Adenoid hypertrophy affects 30.1%-81.1% pediatric patients aged between 2 and 15 years, after which the condition becomes milder 5.

Obstruction at the nasopharynx level causes the child to develop compensatory mechanisms such as mouth breathing.[6,7] This deleterious habit has serious effects including dentoskeletal deformity, characterized by the presence of adenoid facies (medical sign characterized by long, tired face with short upper lip and labial incompetence), maxillary hypoplasia, mandibular prognathism, narrowing of dental arches, severe dental crowding, tooth impaction, anterior open bite, sleep apnea (interrupted breathing during sleep), voice changes, and snoring, which is generally the main cause for a dental visit.[6,7] Otolaryngologists are responsible for the diagnosis and treatment of adenoid hypertrophy, since many medical signs as well as a high grade of hypertrophy will determine the surgical treatment through adenoidectomy.[3,8]

The "gold standard" test to diagnose adenoid hypertrophy is nasopharyngoscopy, which is performed to obtain a direct view of the entire parapharyngeal space.[9,10,11] The presence of hypertrophy and the grade of obstruction are in this way determined.[10] 2D X-ray radiographs such as the projection of the parapharyngeal space and cephalometric radiographs have been used to assess adenoid growth.[12-17] It should be considered, however, that the limitation of X-ray radiography is the two-dimension nature of these images which precludes assessing the real volume of nasopharynx.[18]

Cone-beam computed tomography (CBCT) is a technique characterized by obtaining real-scale images without superimposition, with low doses of radiation, a technique of easy access and low cost, compared to conventional computed tomography. It provides a better tridimensional assessment of hard-and-soft-tissue dental structures. Multiple software programs have been designed and developed to obtain better assessment tools. Tomography proved to be applicable to the evaluation of adenoid hypertrophy[19,20] and to be the most sensitive and specific test, as much as nasopharingoscopy.[21-23]

One of the most important factors to consider in a CBCT is the assessment of the nasopharynx permeability, since breathing difficulty is generated by a decrease in the volume of the airway. Studies have been carried out to find a reference range for volume measurements,[24,25] finding differences among clinical history[26,27] and the absence of these data in the different grades of adenoid hypertrophy.

The current production of more advanced software and tomography equipment makes it possible to obtain better images with the use of minimal radiation. In this context of technological progress, it is now possible to use CBCT to grade adenoid hypertrophy, to determine the volume of the nasopharynx and to refer the patient when needed. This study aimed at determining the volume of the nasopharynx of patients 8 to 12 years old with different grades of adenoid hypertrophy through CBCT.

MATERIALS AND METHODS.

A retrospective, observational study was conducted to evaluate 125 tomography assessments of 8 to 12-year-old pediatric patients (77 females, 48 males), obtained from the database of the Oral and Maxillofacial Radiology Service of Universidad de San Martín de Porres, Lima, Peru, and acquired between 2014-2017. Among the many reasons for CBCT studies, the most frequent was assessing the location of impacted and extra teeth.

Tomography sections were obtained using Promax 3D Mid unit (PlanMeca®, Helsinki, Finland) at values of 90Kv and 10mA and in an X-ray field size of 20x17cm^2. Collected data were assessed by two previously calibrated observers specialized in oral and maxillofacial radiology. Obtained ICC values were 0.090 and 0.909 for linear measurements and 0.981 for volume measurements of the nasopharynx. A perfect degree of agreement was registered for these evaluations.

Determination of the grade of adenoid hypertrophy Romexis 3.6.0 software (Helsinki, Finland) was used to determine the grade of adenoid hypertrophy. The tomography images were placed in a replicable position, taking into consideration the craniometric points of the anterior nasal spine (ANS), posterior nasal spine (PNE), frontonasal suture (nasion point) and a point at the level of the crista galli. Palatal and mid-sagittal planes were determined.

Four grades of adenoid hypertrophy described by Parikh *et al.,*[10] were determined: Grade 1 (healthy), minimal or no increase in the adenoid tissue is shown, the tonsil may be occupying and generating a normal obstruction of 0-25%; Grade 2 (mild), adenoid tissue affecting torus tubarius, obstruction at the level of the choana of 25-50%; Grade 3 (moderate), adenoid tissue affecting torus tubarius and vomer mucosa, obstruction of 50 to 75%; Grade 4 (severe), nearly total obstruction, adenoid tissue touching the soft palate, obstruction greater than 75%. Grades 2, 3 and 4 were considered pathological. In order to determine the grade of hypertrophy in the tomography assessments, qualitative and quantitative evaluations were conducted.

A supplementary qualitative evaluation was based on the methodology used by Major *et al.*[20] The anatomic involvement and the potential grade of the adenoid hypertrophy were observed during the evaluation of the tomography assessment on multiplanar reconstructions. Quantitative evaluation was based on the methods described by Fujioka *et al.,*[17] Caylakli*et al.,*[2] and Oh *et al.,*[23] to determine the A/N (AN) ratio.

The A value was obtained by measuring from the spheno-occipital synchondrosis at the cranial base to the most convex part of the growth of adenoid tissue. The N value was obtained by measuring from the spheno-occipital synchondrosis to PNE. The results of both evaluations. (Figure 1)

Determination of the volume of the nasopharynx

The same software was used with the "3D growing region" tool. The anatomic borders of the nasopharynx proposed by Oh *et al.,*[25] were used, which consisted of the anterior border to a plane perpendicular to the palatal plane at the level of the PNE, and the posterior and superior borders formed by the pharyngeal muscle mucosa. For the lower border, we included the extension of the palatal plane to the posterior border at the level of the pharyngeal muscle mucosa, which was proposed by Aboudara *et al.*[29] (Figure 2)

Figure 1. Measurement of A and N to determinate the A/N ratio using the Romexis 3.6.0 software (Helsinki, Finland). The figure shows an example of a patient with Grade 1 (healthy) hypertrophy and a patient with Grade 4 (severe) hypertrophy.

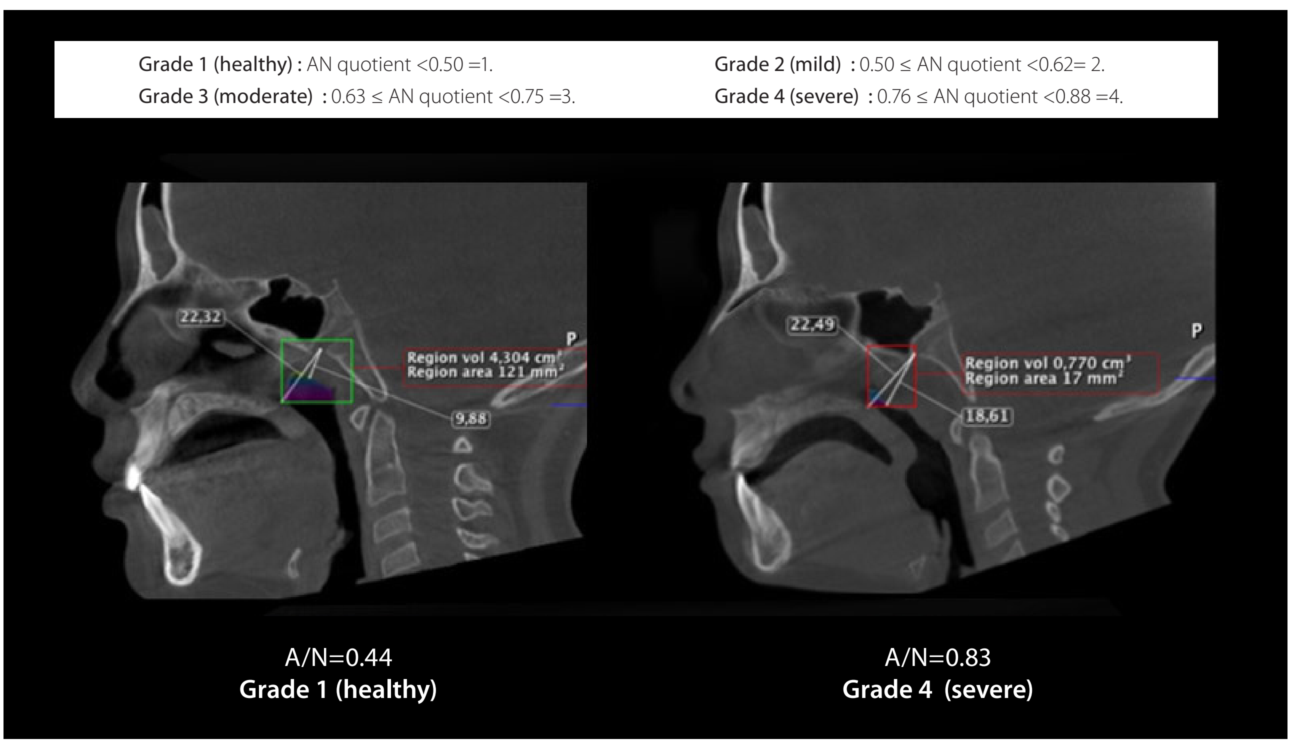

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Figure 2. Volumetric measurement using Romexis 3.6.0 software (PlanMeca®, Finland) in the tomography of Grade 1 (healthy) adenoid hypertrophy, evaluation in sagittal, coronal and 3D renderings cuts.

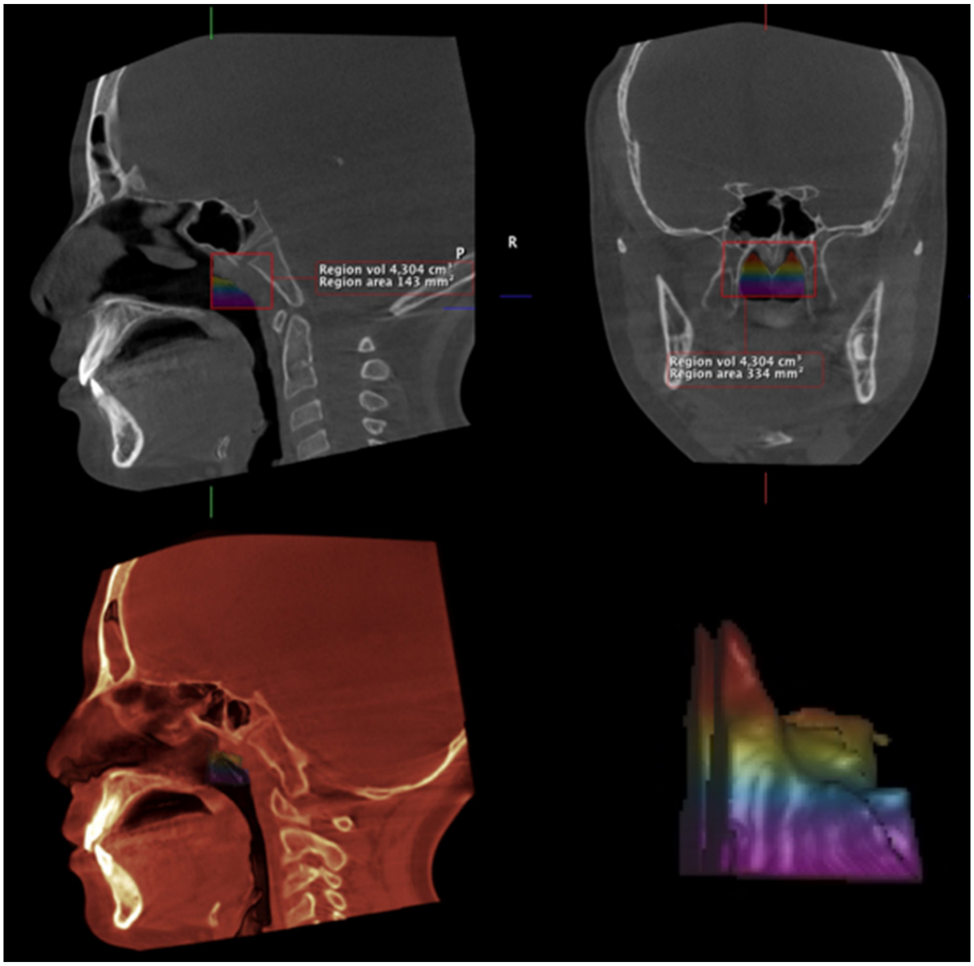

Figure 3. Boxplots of nasopharyngeal airway volume measured by cone beam computed tomography according to hypertrophy grade.

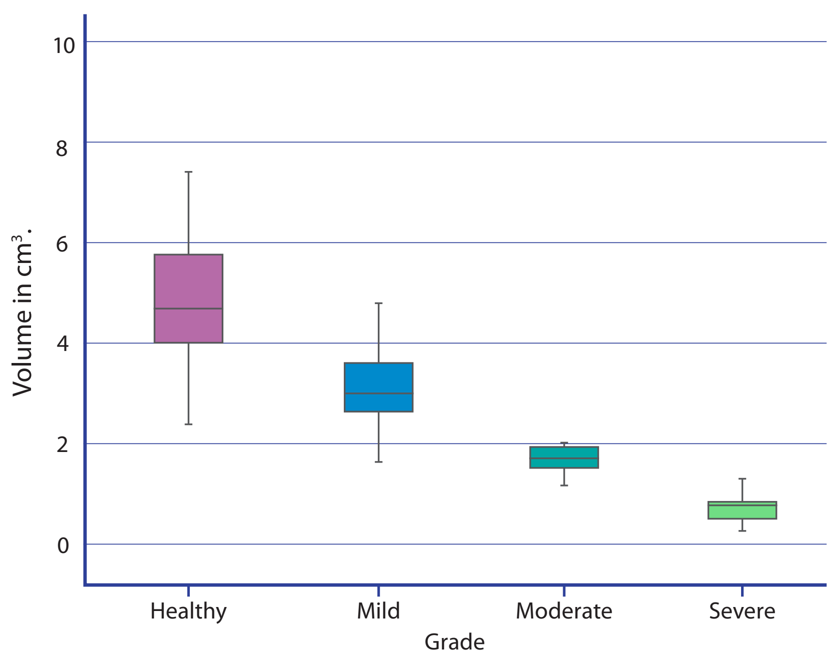

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Figure 4. Boxplots of nasopharyngeal airway volume measured by cone beam computed tomography, according to age.

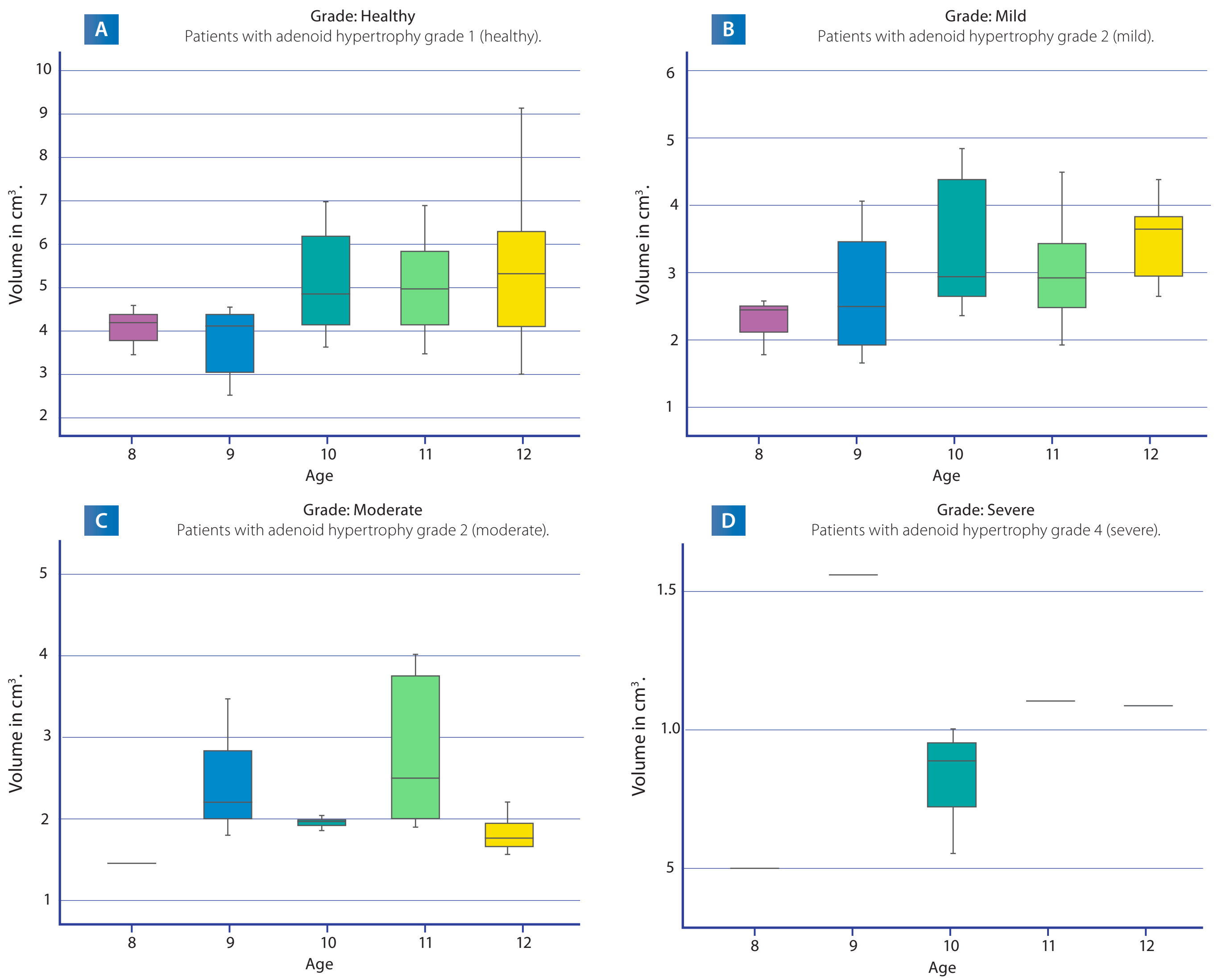

Table 1. Grade of adenoid hypertrophy as evaluated by cone beam computed tomography.

Grade	Frequency	Percentage
Healthy	55	44.0
Mild	46	36.8
Moderate	17	13.6
Severe	7	5.6
Total	125	100.0

RESULTS.

Descriptive statistics show a distribution of tomography assessments, whose frequency increases with age. The sample was composed of a higher percentage of tomography assessments of male patients (61.6%), while females accounted for 38.4%. The prevalence of pathological hypertrophy was 56%, including mild, moderate, and severe grades. (Table 1)

The mean volume of the nasopharynx was 3.68+-1.6cm³, regardless of the grade of adenoid hypertrophy. There were few cases with extreme low or high values.

The volume of the nasopharynx significantly decreases

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as the grade of adenoid hypertrophy increases (4.985cm³, standard deviation (SD) 1.293cm³ for grade 1; 3.375cm³ SD 0.846cm³ for grade 2; 2.154cm³ SD 0.789cm³ for grade 3; and 0.944cm³ SD 0.342cm³ for Grade 4). (Figure 3)

Nasopharynx volume values in patients with Grade 1 adenoid hypertrophy are quite homogeneous, regardless of sex (4.988cm³ SD of 1.123cm³ for males, and 4.980cm³ SD of 1.519cm³ for females).

These values slightly increase with age (from 2.421cm³ SD of 0.409cm³ at 8 years, to 3.754cm³ SD of 2.810 cm3 at 12 years), in contrast with volumetric values observed in grades 2, 3 and 4, which are very variable (Figure 4).

DISCUSSION.

Pathological adenoid hypertrophy is of primary importance for the dentist, because of the effects it may have at a dento-maxillary level, which could be irreversible particularly in adulthood considering the high cost of corrective treatments for patients; thus, it is essential to take into account the high prevalence of this pathology.

In the present study, a pathological adenoid hypertrophy prevalence of 56% was found. Pereira *et al.,*[5] reported a prevalence range of 42% to 70% in their systematic review according to data published in studies whose sampling methodology was non-probabilistic, and 34% in randomized studies. A similar percentage of 52.3% was reported by Kidermann *et al.,*[11] who radiographically assessed 130 pediatric patients of 2 to 12 years with fiberoptic flexible nasal endoscopy.

Bitar *et al.,*[29] found an incidence of 57.7% of which 1.6% showed a choanal-type hypertrophy, which is similar to Grade 4 in this study. The slight difference may be due to the methodology used for Bitar *et al.,*[29] who based their prevalence study on radiographic analysis, not using the A/N ratio but the percentage of obstruction according to Jeans *et al.*[8]

Nasopharyngoscopy was only used in 12.2% of all cases, which could have led to many cases of severe hypertrophy to be considered moderate. Farid *et al.,*[19] indicate that the incidence of adenoid hypertrophy can increase to 87% only if patients with mouth breathing are evaluated. Lira *et al.,*[6] reported a reduction of nasopharyngeal and oropharyngeal airspace in their study which included 43 patients with anterior open bite, they also considered the strong association with adenoid hypertrophy.

However, the limitation was that airspaces were evaluated on lateral radiographs; Feres *et al.,*[30] found a relationship between the presence of adenoid hypertrophy with skeletal malocclusion II and mandibular hyperdivergence. Contrasting with these results, this study did not connect the presence of dentoskeletal deformities or clinical symptomatology with adenoid hypertrophy; volumetric measurement of the nasopharynx has an equal importance when determining adenoid hypertrophy, in this regard there are no data that assess that relation, thus it is still considered subject of future studies.

The grade of adenoid hypertrophy has been reported by Parikh *et al.,*[10] who defines 4 Grades: Grade 1 (healthy) as a normal hypertrophy, Grade 2 (mild), Grade 3 (moderate), and Grade 4 (severe). Bravo *et al.,*[12] only define as pathological adenoid hypertrophy Grades 3 and 4, as these are mainly associated symptoms. However, this study also considers Grade 2 (mild) within pathological hypertrophy by considering volumetric decrease of the nasopharynx as a real cause of mouth breathing, and that there is already a significant decrease in grade 2 in comparison with a normal permeable airway (from 4.985+-0.846 to 3.375+-0.789cm³).

Major *et al.,*[20] reported a sensibility of 88% and a specificity of 93% for CBCT, as an assessment technique for the four grades of adenoid hypertrophy, compared with nasopharyngoscopy. Its main assessment was qualitative based on the exploration of the tomography studies and considering the anatomical implications of the original classification of Parikh *et al.*[10]

Similarly, Pachêco-Pereira *et al.,*[21] report a reliability of more than 80% in the hypertrophy diagnosis by oral and maxillofacial radiologists; nonetheless, diagnostic precision considerably decreases when other specialists in dentistry, such as orthodontists, assess tomographic images (ICC=0.39; range of ICC of 0.00-0.74). The methodology was applied in this study included a supplementary qualitative evaluation, which in contrast quantitative evaluation alone, calls for greater training and experience of the specialists who visualize and evaluate the tomography sections.

Application of the A/N ratio, as conducted by Fujioka *et al.,*[7] to determine the presence of adenoid hypertrophy, has been well established. First, a validation of the method was conducted by Caylakli *et al.*,[2] in cephalometric radiographs, where a positive relation between A/N values and data obtained from nasopharyngoscopy (r=0.511; $p<0.001$) was found. Subsequently, Feres *et al.*,[16] determined that the A/N ratio has the best correlation (from all described methods) with nasopharyngoscopy (R2 of 0.971).

Finally, Oh *et al.*,[23] validated the A/N ratio at a tomographic level for four grades of adenoid hypertrophy. Because of this data, the present study also applied the A/N ratio, considering it reliable, reproducible and of easy application for the specialists who evaluate CBCTs.

As for volumetric measures of the nasopharyx, there are disagreements in published data; Oh *et al.*,[25] in a study in which 60 patients were assessed, reported a mean of 2.954+-2.122cm^3 for a normal nasopharynx volume, even though there are slight differences between volumes according to patients´skeletal pattern I, II, or III. These variations are not statistically significant.

Based on these results, this research did not conduct any exclusion of patients on the basis of their skeletal patron; for Pachêco-Pereira *et al.*,[26] a normal volume of the nasopharynx is 6.990+-2.845cm^3; while Aboudara *et al.*,[27] considers a normal mean of 3.667+-1.414cm^3.

The present study reports a mean of 4.985cm^3+-1.293cm^3. The main reason of disagreement lies in how authors consider the borders of the nasopharynx, not reaching a consensus for the lower or upper borders.

For Oh *et al.*,[23] the lower border must be a plane drawn from PNE to the first cervical vertebra, while for Pachêco-Pereira *et al.*,[26] the lower border is parallel to the Frankfurt plane passing the uvula and other planes at basion level and C1. This study used the lower border formed by the extension of the palatal plane to the posterior edge of pharyngeal muscle mucosa, as suggested by Aboudara M, *et al.*[27] As such we used this methodology as it is considered easy to reproduce and has less variation, and the Romexis software makes it possible to delimit it, without the need of an external design program.

CONCLUSION.

Adenoid hypertrophy is a pathology of high prevalence. The use of CBCT in the diagnosis of adenoid hypertrophy and in the determination of its grade is reliable. It is an alternative to nasopharyngoscopy, taking into account that it is a non-invasive procedure. The A/N ratio together with a qualitative tomographic evaluation, are effective methods for the determination of adenoid hypertrophy grades.

CBCT together with the Romexis 3.6.0 software tools, can quantify nasopharynx volume, considering the borders described in this publication, avoiding the use of more complex external programs.

Conflict of interests: The authors declare no conflicts of interest.

Ethics approval: Approved by the Research Review Committee No. 028-2017 (10/19/2017) and by the Research Ethics Committee No. 007-2017 (24/10/2017), of the Facultad de Odontología de la Universidad de San Martín de Porres.

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